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NEUROLOGIC PICTURE OF HERNIATIONS OF THE NUCLEUS PULPOSUS IN THE LOWER PART OF THE LUMBAR REGION

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In June 1939, one of us (R. G. S.) in collaboration with Bradford [1] suggested a group of criteria that could be relied on in the clinical diagnosis of a herniated nucleus pulposus at the fourth or fifth lumbar interspace. These criteria were based on a series of 10 cases in which surgical procedures were done without the aid of contrast myelography. Now, after a larger experience, we are reporting on the success of these criteria and amplifying those points which have been shown to be of the greatest importance in diagnosis.

We have avoided the term "protruded intervertebral disk" because we do not consider that it accurately designates the pathologic process in many cases. In order for the disk to produce symptoms we believe the annulus fibrosus must have been ruptured or torn, and if the nucleus pulposus is extruded through the tear a certain group of symptoms will usually appear; if the nucleus is not so extruded, however, another set of symptoms will be encountered. Therefore, we shall use the term "rupture of the intervertebral disk," with or without herniation of the nucleus pulposus.

It cannot be emphasized too often that a history of recurrent pain low in the back and sciatic pain is not always indicative of disease of an intervertebral disk. Neoplasms within the spinal canal or along the course of the sciatic nerve, rectal or pelvic pathologic conditions and diseases of the osseous structures must be ruled out by clinical and roentgen examination before a clinical diagnosis of ruptured intervertebral disk can be made.

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1. Spurling, R. G., and Bradford, F. K.: Neurologic Aspects of Herniated Nucleus Pulposus at the Fourth and Fifth Lumbar Interspaces, J. A. M. A. **113**:2019-2022 (Dec. 2) 1939.

ANATOMIC CONSIDERATIONS

A thorough knowledge of the anatomic relations in the lower lumbar portion of the spine is essential to a clear understanding of the symptoms and signs of a herniated nucleus pulposus at this level. The

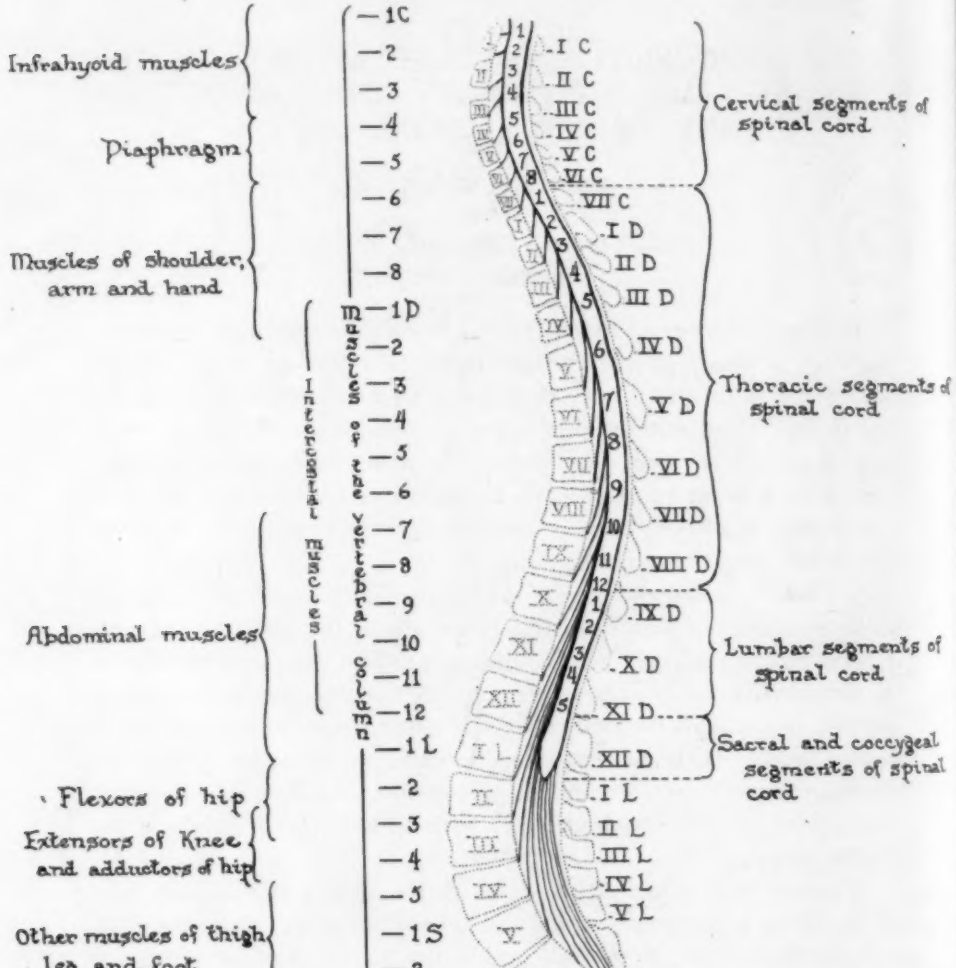
Infrahyoid muscles
Diaphragm
Muscles of shoulder, arm and hand
Abdominal muscles
Flexors of hip
Extensors of Knee and adductors of hip
Other muscles of thigh leg and foot
Perineal and anal muscles
Intercostal Muscles
Muscles of the vertebral column
Cervical segments of spinal cord
Thoracic segments of spinal cord
Lumbar segments of spinal cord
Sacral and coccygeal segments of spinal cord

Fig. 1.—Diagram showing the levels of the various segments of the spinal cord and nerve roots with reference to the vertebral column. The table at the left indicates the muscles innervated by the various roots. (From an illustration in Ranson, S. W.: Anatomy of the Nervous System, Philadelphia, W. B. Saunders Company, 1931.)

relation of the fifth lumbar nerve to the disk between the bodies of the fourth and fifth lumbar vertebrae and the relation of the first sacral nerve to the lumbosacral disk are especially important, since over 96 per cent of ruptured disks occur at these levels.

The spinal cord terminates opposite the intervertebral disk below the first lumbar vertebra (fig. 1). The nerve roots of the cauda equina are freely mobile in the large lumbar canal except as they approach

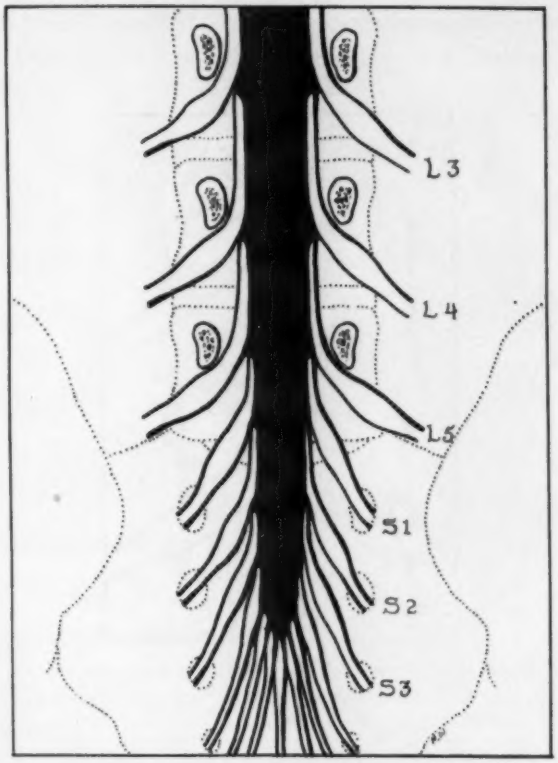

Fig. 2.—Diagrammatic representation of the thecal sac and the lower lumbar and sacral nerves to the pedicles and intervertebral disks of the lower part of the spine.

their points of exit, where they are fixed. It is therefore apparent that only those roots that are compressed near their points of exit cause symptoms and signs of localizing value unless the lesion is a tremendously large one that compresses uniformly the roots of the cauda equina. At the level of the fourth intervertebral space the fifth lumbar nerve lies in the subarachnoid space, fixed laterally against the dura. The dural sleeve of the fifth lumbar nerve below the level of the fourth

lumbar interspace passes downward beneath the pedicle of the fifth lumbar vertebra through the intervertebral foramen (fig. 2). The same relations exist between all the lumbar nerves and their respective disks. In contrast, the dural sleeve of the first sacral nerve separates from the thecal sac above the lumbosacral disk and can thus be compressed without deforming the sac. A laterally placed lesion of the fourth disk, therefore, would first compress the fifth lumbar nerve, and, furthermore, the fourth lumbar nerve could not be compressed by a lesion at this point unless it protruded into the intervertebral foramen (fig. 3). Likewise, at the fifth lumbar disk the first sacral nerve is compressed first.

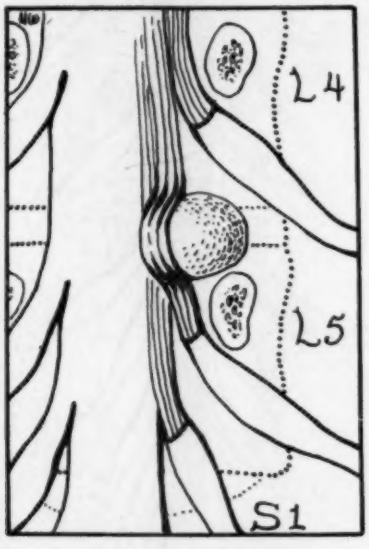

Fig. 3.—Diagram illustrating the mechanism of compression of the roots of the fifth lumbar and first sacral nerves from a lateral herniation of the nucleus pulposus at the fourth lumbar interspace.

Most anatomic investigators have failed to demonstrate a sensory nerve supply to the intervertebral disk. It has been repeatedly shown, however, that the posterior longitudinal ligament contains a profuse supply of sensory nerves. These anatomic data have not coincided with our clinical observations, because we have repeatedly had patients who complained of pain in the back during operation with local anesthesia when the annulus fibrosus was manipulated. Consequently, Roofe [2] undertook a reinvestigation of the innervation of the intervertebral disk.

2. Roofe, P.: The Innervation of the Annulus Fibrosus and the Posterior Longitudinal Ligament at the Fourth and Fifth Lumbar Level, Arch. Neurol. & Psychiat., to be published.

and his researches have conclusively demonstrated a profuse supply of sensory nerves in the annulus fibrosus as well as in the posterior longitudinal ligament (fig. 4). Furthermore, his investigations indicate that the nerve supply to the annulus fibrosus is through a recurrent branch just distal to the posterior root ganglion. After separating from the main trunk, it reenters the intervertebral foramen and supplies the liga-

Fig. 4.—Photomicrograph of a strand of unmyelinated nerve fibers in the annulus fibrosus. Gold chloride technic of Garvin; × 145 (Roofe [2]).

mentous structures two vertebrae lower than the exit of the spinal nerve (fig. 5). This anatomic fact sheds much light on the symptoms both in cases in which the pathologic process is limited to the ligamentous structures of the lower part of the lumbar and the lumbosacral region and in those in which a tear of the annulus fibrosus has led to herniation of the nucleus pulposus.

It is apparent from the relations just indicated that a knowledge of the exact course and distribution of the fourth and fifth lumbar and first sacral nerves, motor and sensory, is essential to a proper clinical understanding of symptoms due to lesions in these areas. In the presence of a herniated nucleus pulposus the usual finding of hypesthesia or anesthesia of the lateral aspect of the leg probably depends on combined involvement of the fifth lumbar and the first or second sacral dermatome, since involvement of a single spinal nerve rarely gives objective sensory deficit. However, paresthesias may result from involvement of a single spinal nerve. The dermatome of the fifth lumbar nerve is small, but with associated loss referable to the first sacral nerve

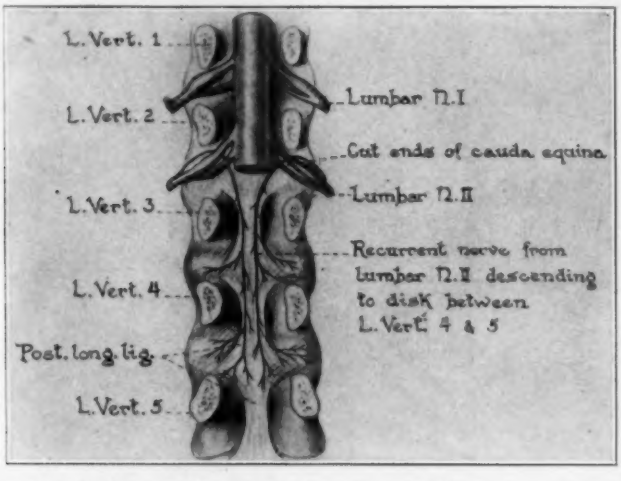
L. Vert. 1
L. Vert. 2
L. Vert. 3
L. Vert. 4
Post. long. lig.
L. Vert. 5
Lumbar N.I
Cut ends of cauda equina
Lumbar N.II
Recurrent nerve from lumbar N.II descending to disk between L. Vert. 4 & 5

Fig. 5.—Distribution of the second recurrent lumbar nerve to the region of the third and fourth lumbar vertebrae and the fourth and fifth intervertebral disks. (From an illustration in Spurling and Bradford.[1]).

there would probably be an area of hypesthesia on the anterolateral aspect of the leg. Similarly, the first and second sacral nerves would necessarily be affected to give hypesthesia or anesthesia of the more lateral aspect of the leg. The small gluteal dermatomes are rarely involved except in lesions sufficiently large to compress severely the dural sac (fig. 6).

CLINICAL CONSIDERATIONS

Material Studied.—The clinical data presented in this paper were accumulated from 125 consecutive laminectomies performed for intractable pain low in the back and sciatic pain. There were 92 cases of frank rupture of the annulus fibrosus with herniation of the nucleus pulposus. In the remainder of the series the final diagnosis was hyper-

trophy of the ligamentum flavum in 18 cases, neoplasm in the lower lumbar canal in 4 cases and "negative exploration" in 11 cases. In a previous communication [3] we have analyzed critically a cross section of the entire group. Our chief consideration here is ruptured intervertebral disk with herniation of the nucleus pulposus. This lesion occurred at the fifth lumbar interspace in 51 cases, at the fourth in 39, at the third

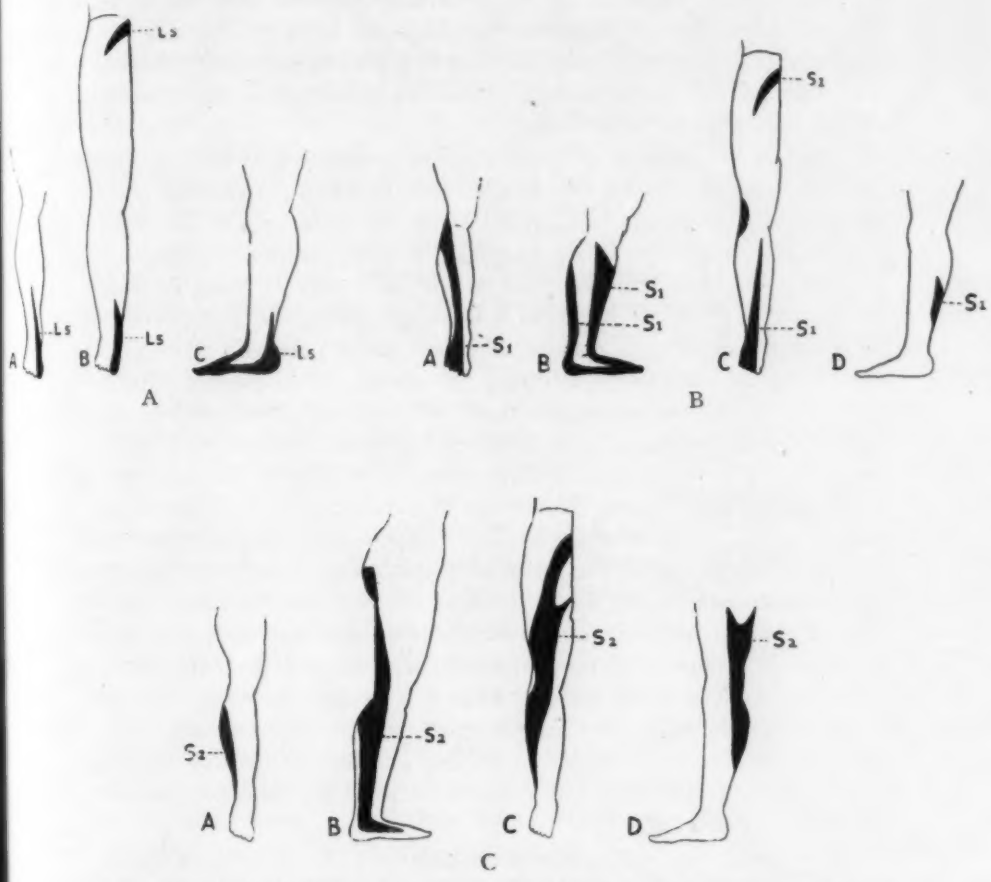

Fig. 6.—Approximate dermatomes of (*A*) the fifth lumbar, (*B*) the first sacral and (*C*) the second sacral nerve roots. In illustration *A*, *A* represents the ventral, *B* the dorsal and *C* the lateral view. In illustrations *B* and *C*, *A* represents the ventral, *B* the lateral, *C* the dorsal and *D* the mesial view. (Modified from illustrations in Tilney, F., and Riley, H. A.: The Form and Functions of the Central Nervous System, New York, Paul B. Hoeber, Inc., 1938. The three parts of figure 6 have been published also by Spurling and Bradford.[1])

3. Bradford, F. K., and Spurling, R. G.: Intraspinal Causes of Low Back and Sciatic Pain: Results in Sixty Consecutive Low Lumbar Laminectomies, Surg., Gynec. & Obst. **69**:446 (Oct.) 1939.

in 1 and at both the fourth and the fifth in 1. The incidence, therefore, of ruptured intervertebral disk at the fourth and fifth lumbar interspaces in our series was 99 per cent.

Twenty-seven patients with this condition were subjected to operation on the basis of clinical findings alone, i. e., without the use of contrast myelography.

Symptoms.—In cases of ruptured intervertebral disk an accurate history is perhaps as important in diagnosis as it is in cases of tic douloureux. The story from an observing patient may be so characteristic that not only is the probable diagnosis indicated but the exact level of the lesion can be prophesied.

The initial symptom of disease of an intervertebral disk is, almost without exception, pain low in the back (lumbago). In the absence of a definite traumatic history, the onset of acute pain in the back is usually associated with lifting in a bent-forward position or with sudden torsion of the trunk. The pain in the back may be mild or severe, but in the majority of instances it is incapacitating. It is relieved only by absolute immobility, usually in a recumbent position. It is always intensified by movements affecting the spine. As the acute pain subsides and the patient becomes ambulatory, he usually finds that bending, and especially lifting in a bent-forward position, causes recurrence of the pain. The point of maximum intensity is usually the midline, but it may be to one side of the midline or may even be most severe over one or both sacroiliac articulations. Repeated attacks of "low back disability" may precede the onset of sciatic pain. However, the sciatic pain may appear shortly after the onset of the initial lumbago. As the pain in the leg increases in intensity, the pain in the back may lessen or entirely disappear. The pain in the leg may not be uniform along the course of the sciatic nerve. Points of greatest intensity are likely to be in the gluteal region, the posterior part of the thigh, the back of the knee or the lateral aspect of the leg and ankle. During the acute episode the pain both in the back and in the leg is intensified by coughing, straining or sneezing.

Paresthesias are a common accompaniment of the pain in the legs. Many patients complain of tingling, prickling, electrical shocks, coldness or numb sensations in any one of the involved dermatomes. Paresthesias below the knee in the lateral aspect of the leg or foot or in the second, third and fourth toes are characteristic of lesions at the fifth lumbar interspace. Paresthesias involving the great toe, the top of the foot and the medial aspect of the heel are characteristically associated with lesions at the fourth lumbar interspace. Paresthesias are usually not constant but appear with certain postures or on coughing, straining or sneezing.

Weakness is not usually a major complaint, but not infrequently the patients state that they favor the painful leg. In some instances, however, definite muscular weakness limited to one group of muscles is observed by the patient.

Sensory loss limited to the involved dermatomes is frequently described by an observing patient. However, in most instances paresthesias take precedence in the symptoms.

Signs.—Stiffness of the lumbar portion of the spine is a prominent clinical feature but not nearly so important diagnostically as severe sciatic pain. The normal ventral lumbar curve may be completely obliterated. The absence of the curve is due to spasm of the erector spinae muscles and is especially well demonstrated when the patient bends forward. The rigidity of the lumbar portion of the spine is in no way dissimilar from that occurring in severe articular disease. Listing to one side is a common finding, the ilium usually being higher on the side of the lesion. Limitation of flexion of the lumbar portion of the spine is always present in patients who are complaining of pain in the back but may be entirely absent in patients in whom pain in the back has disappeared.

The leg-raising sign as described by Lasègue [4] is most important in differentiating tenderness of the sciatic nerve from painful hamstring muscles. As was pointed out in the original description, patients with severe sciatica keep the knee flexed and are unwilling to put the heel on the floor, thus preventing direct tension on the nerve. The Lasègue test is performed with the patient supine. The thigh is raised until it forms a right angle with the trunk, and the leg, which has remained flexed, is extended until pain begins along the course of the sciatic nerve. Then, without further movement of the leg or thigh, the foot is passively dorsiflexed to determine whether the additional pull on the sciatic nerve intensifies the pain. We believe that this test gives a positive result in all cases of herniation of the nucleus pulposus involving the components of the sciatic nerve. A modification of the Lasègue test for use in cases of severe acute sciatic pain is performed as follows: With the patient lying supine and the legs and feet outstretched, the foot is quickly dorsiflexed. Acute pain along the course of the nerve following this maneuver is indicative of irritation of the sciatic nerve.

Naffziger and Jones [5] have described a test which we feel is of extreme importance in the diagnosis of intraspinal lesions. It is performed by occluding both jugular veins until a sense of fulness in the

4. Lasègue, C.: Considération sur la sciatique, Arch. gén. de méd. **2**:558, 1864.

5. Naffziger, H. C., and Jones, O. W.: Dermoid Tumors of the Spinal Cord, Arch. Neurol. & Psychiat. **33**:941 (May) 1935.

head is experienced by the patient and until the face is flushed. If the pain in the back of the leg or paresthesias in the leg are reproduced by this maneuver, we consider the finding pathognomonic of intraspinal disease.

Local tenderness on pressure over the spinous process of the involved vertebra may occasionally elicit pain in the distribution of the sciatic nerve. When present, this sign is highly indicative of herniated nucleus pulposus at this level.

Demonstrable muscular weakness is usually not an important aid in diagnosis. The patient confuses pain on using the affected muscles with weakness, and testing is usually unsatisfactory because of pain on exertion of motor power. However, occasionally definite paresis or paralysis of the anterior tibial, peroneal, extensor hallucis or extensor digitorum communis muscles is observed. Fibrillation of the muscles of the leg is occasionally seen and when present may be of great importance in diagnosis.

The sensory changes are most important not only in arriving at a diagnosis of herniated nucleus pulposus but in accurate localization of the lesion. When the herniation occurs at the fifth interspace the first and second sacral nerve roots are primarily involved. When the herniation occurs at the fourth interspace the fifth lumbar and first sacral nerve roots are most severely compressed. With herniation at the third lumbar interspace the fourth and fifth lumbar nerve roots are primarily involved. Sensory changes in the dermatomes below the knee are usually more easily demonstrated than are those in the perianal region and on the backs of the thighs. Although the areas of hypesthesia can usually be demonstrated with pinprick, tests with cotton wool or hot and cold test tubes frequently reveal a definite area of hypesthesia where results with pinprick are equivocal. In plotting sensory changes great care and patience are required, and it is extremely important not to ask leading questions. The stimulus should be applied first to one leg and then to the other to eliminate the natural tendency to appreciate better the last-applied stimulus. When there is doubt as to the accuracy of the observations, the test should be repeated at subsequent examinations. We have encountered a number of cases in which on one day the sensory findings were equivocal and yet at the next examination a definite sensory pattern was demonstrated.

More important in diagnosis than actual sensory loss is the "causalgic-like" discomfort which is often produced by stimulation in the hypesthetic zone. Stroking the skin of the involved dermatomes may produce a "needle and pin" sensation or "electric shocks" sharply limited to the involved segment. This hyperesthesia may overshadow the hypesthesia.

Patients with herniation of the nucleus pulposus at the third, fourth or fifth lumbar interspace have in common pain low in the back, sciatic pain, hypesthesia or anesthesia in areas below the knee. It is often possible to differentiate accurately the maximum involvement in the fourth and fifth lumbar or in the first and second sacral dermatomes. When the lesion is at the third lumbar interspace, sensory changes in the fourth and fifth lumbar dermatomes should predominate. With lesions at the fourth interspace, hypesthesia in the fifth lumbar and the first sacral dermatome is most pronounced. With lesions of the lumbosacral disk hypesthesia in the first and second sacral dermatomes with sparing of the fourth and fifth lumbar dermatomes is characteristically observed.

If the ankle jerk is unchanged and paresthesia or hypesthesia in the leg is more anterior, including the great toe and the heel, the fourth lumbar disk is probably involved. If the ankle jerk is diminished or absent and the hypesthesia is more posterolateral, including the lateral aspect of the foot and perhaps the second, third and fourth toes, the herniation is probably at the lumbosacral disk.

Our experience with the third lumbar disk is limited to 1 proved case; therefore, reliable data cannot be presented for lesions at this level. In this 1 case, however, the findings were definite and conformed to all of our anatomic deductions. The maximum hypesthesia was in the fourth and fifth lumbar and the first sacral dermatomes, with paresthesias affecting these areas. The knee jerk was diminished; the ankle jerk was normal. The other signs of disability of the lower part of the back and sciatic pain were essentially the same as with herniations at the fourth lumbar interspace.

In summarizing the signs and symptoms we may tabulate the localizing data as follows:

Third lumbar interspace

1. Disability of the lower part of the back, with local tenderness at the third lumbar spine and reduction of lumbar lordosis.

2. Positive Lasègue test.

3. Positive Naffziger test, producing paresthesias in the fourth and fifth lumbar dermatomes.

4. Reduction or absence of the knee jerk; ankle jerk unchanged.

5. Hypesthesia and paresthesias in the fourth and fifth lumbar dermatomes.

Fourth lumbar interspace

1. Disability of the lower part of the back with stiffness of the lumbar portion of the spine and localized tenderness at the level of the fourth lamina, with reduction of lumbar lordosis.

2. Positive Lasègue test.

3. Positive Naffziger test with paresthesias involving the fifth lumbar, the first sacral and perhaps the second sacral dermatomes.

4. Ankle and knee jerks uninvolved.

5. Hypesthesia and paresthesias in the fifth lumbar and first sacral dermatomes.

Fifth lumbar interspace

1. Disability of the lower part of the back with absence of lumbar lordosis and localized tenderness to pressure over the fifth lumbar vertebra.

2. Positive Lasègue test.

3. Positive Naffziger test, producing paresthesias radiating into the first and second sacral dermatomes.

4. Diminution or absence of ankle jerk.

5. Hypesthesia involving the first and second sacral dermatomes.

COMMENT

The recurrent episodes of pain low in the back which almost invariably precede the sciatic pain of herniated nucleus pulposus are probably due to disease of the intervertebral disk and the posterior longitudinal ligament. Tearing of these structures either from frank trauma or as a result of repeated small traumas incident to weight bearing may be the only cause. Of course, the susceptibility of the disk to trauma may be due to congenital weakness or to degenerative changes in this structure. With tearing of the annulus fibrosus and the subsequent inflammatory reaction therefrom, the sensory nerve endings, with which the structure is richly supplied, are stimulated; hence the pain in the back. The pain remains localized to the back unless the tear is sufficiently large to permit extrusion of the nucleus pulposus or detached portions of the annulus fibrosus into the spinal canal. When such extrusion occurs, one or more roots of the cauda equina may be impinged on, and then pain in the leg results. Whether or not demonstrable neurologic signs occur depends on the degree of compression of the nerve roots.

Many patients with injury to the annulus fibrosus and even recurrent attacks of lumbago undoubtedly recover without the development of a herniated nucleus pulposus that impinges on the nerve roots. It must be remembered, however, that the nucleus may extrude through a median rupture of the annulus fibrosus without causing root compression sufficient to produce pain in the leg. The dominant symptom in such circumstances would continue to be local pain in the back.

Tears of the annulus fibrosus apparently are more likely to occur in the posterolateral aspect, owing to the poor lateral development of the posterior longitudinal ligament, which supports the annulus fibrosus. At the third lumbar interspace such a posterolateral herniation compresses primarily the fourth lumbar nerve root just above its exit from the dural sleeve. At the fourth lumbar interspace the fifth root is thus primarily compressed. However, if the herniation occurs far lateralward at either level the root corresponding to the interspace may be compressed at the intervertebral foramen. If the herniation is large, the thecal sac may be compressed from the side, and, in addition, the lower nerve roots on the same side may be sufficiently compressed to produce a neurologic deficit. Rarely, however, is disruption of the disk sufficiently large to compress uniformly all the roots of the cauda equina, thereby producing diffuse bilateral signs.

It is the compression of one or more components of the sciatic nerve which gives rise to the severe "sciatica." From involvement of either the fourth or the fifth lumbar or the first sacral root alone, pain can occur along the entire course of the nerve. That the knee jerk may be diminished or absent with herniation at the level of the third lumbar interspace is in keeping with the accepted innervation of the quadriceps femoris muscle by the fourth and fifth lumbar nerves. That the ankle jerk is unaffected by typical herniations at the fourth lumbar interspace and is diminished or absent with herniations at the fifth lumbar interspace is also consistent with the accepted innervation of the gastrocnemius and soleus muscles by the first and second sacral nerves.

That these neurologic symptoms and signs are accurate and reliable is attested by the fact that during the past eight months we have successfully removed 26 consecutive herniations of the nucleus pulposus without confirmation with iodized oil or other contrast mediums. In the twenty-seventh case, confirmation of the clinical findings was not made at operation. In the same period we have used iodized oil in 28 cases for verification of the lesion. In this group there were 12 cases in which the clinical findings were sufficiently clearcut to justify surgical exploration without iodized oil but in which for various reasons roentgen verification was demanded. In the group in which iodized oil was used there were 4 failures of verification. In 2 cases of this group the clinical picture definitely pointed to herniation at the fifth lumbar interspace, yet the iodized oil study indicated the lesion to be at the fourth lumbar interspace. The accuracy of the clinical findings in both instances was confirmed, whereas the defects observed with iodized oil were explained only by the presence of a hypertrophied ligamentum flavum. On the basis of our experience thus far we feel much safer in subjecting patients

to operation when the clinical findings are clearcut than when an iodized oil study is necessary for accurate diagnosis.

SUMMARY

1. The diagnosis of rupture of the intervertebral disk with herniation of the nucleus pulposus in the lower lumbar region can be made in many instances from clinical findings alone. In fully 50 per cent of cases, not only can the diagnosis of the lesion be made, but the exact level can be predicted accurately.

2. A careful consideration of the clinical findings is of importance not only in selecting cases for operation without contrast myelography but in making a more conservative selection of cases for the injection of iodized poppyseed oil.

3. The neurologic findings of herniated nucleus pulposus are not peculiar to this one clinical entity, since neoplasms within the spinal canal or along the course of the sciatic nerve, rectal or pelvic pathologic conditions and diseases of the osseous structures may simulate this clinical picture. The need, therefore, of a complete clinical study of all patients with disability of the lower part of the back and of the leg before contrast myelography or exploration is resorted to is apparent.

PATHOLOGY OF THE INTERVERTEBRAL DISK

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INTRODUCTION

There is a growing appreciation of the significance of the intervertebral disk in its relationship to spinal disease. When it is remembered that the disks make up a full quarter of the total length of the presacral portion of the spinal column, it is evident that these structures constitute an extensive organ. In point of fact it may be said that the greater majority of conditions resulting in spinal deformity or in derangement of spinal function are primarily the outcome of involvement of the intervertebral disks.

For a clear appreciation of the pathologic pictures and notably for the interpretation of pathologic processes and their genesis, a thorough acquaintance with the structure and function of the disks is essential. From decade to decade there are considerable variations in both the anatomic character and the physiologic competence of the disks; hence it is necessary to consider their developmental history. Nonetheless a fine distinction at any given age period between what is normal and what pathologic is often difficult to draw. It is this difficulty which emphasizes the need for examination of the disk in terms of a continuous process of change. For this point of view we are indebted to the late Professor Schmorl, of Dresden, Germany, whose work, together with that of his pupils, has served to develop what we feel to be the fundamental approach to pathologic conditions of the disk. Schmorl's pioneer effort has been the stimulus for much further investigation along such lines.

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For a complete bibliography of the subject the reader should consult Saunders, J. B. deC. M., and Inman, V. T.: The Intervertebral Disc: A Critical and Collective Review, Internat. Abstr. Surg. **69**:14-29, 1939; in Surg., Gynec. & Obst., July 1939.

ANATOMIC AND HISTOLOGIC ASPECTS OF THE NORMAL DISK

The interval between each two vertebral bodies is occupied by the intervertebral fibrocartilaginous disk. The vertical thickness of each disk varies from region to region, being thinnest from the third to the

Fig. 1.—*A*, dissection of the cartilage plate of a lumbar vertebra. Note the central zone, through which appears the underlying bone. Peripherally its blending with annular fibers is evident. In the central zone a group of fissures filled with gelatinous scars are seen. *B*, sagittal section of a normal thoracic disk from a man aged 21. Note the three components of the disk.

seventh thoracic and thickest in the lumbar segment. Ventral and dorsal inequalities in thickness conform to and are in some measure responsible for the characteristic curves of the spinal column. The essential unit is made up of three parts: the annulus fibrosus, the nucleus pulposus and the cartilage plates. This concept of the disk as a tripartite unit is of the greatest importance for the interpretation of the various morbid processes which affect these structures.

The cartilage plates cover the end surfaces of the opposed vertebral bodies. On gross examination they are well defined centrally but disappear marginally by blending with the annulus fibrosus (fig. 1 *A*). Microscopically the plate is composed predominantly of hyaline cartilage, which is, however, definitely more fibrous at the periphery. The cells of that surface, in apposition to the bony centrum, are irregularly arranged whereas those of the internal aspect, facing the nucleus pulposus, lie for the most part parallel to the surface (fig. 1 *B*). The average plate is approximately 1 mm. in thickness but is usually thinner at the center. Marginally the cartilage blends imperceptibly into the fibers of the annulus, and at this point its cellular elements tend to orient themselves in the direction of the entering fibers. The surface opposed to the bone is found unsupported at the intertrabecular intervals, where the bone marrow is found in direct contact with the cartilage plate. The internal surface is sharply delineated from the nuclear material. However, delicate fibers passing vertically from the nucleus can be discerned entering the plate by suddenly changing their axis and paralleling its surface.

The nucleus pulposus occupies approximately the center of the disk, a little nearer the posterior than the anterior aspect. The transition between nucleus and annulus is progressively more indefinite the younger the specimen. Normally the nucleus is soft and elastic, somewhat slimy to the touch, and, because of its inherent turgor, bulges on section, above the cut surface. In what may otherwise be considered a healthy disk one frequently encounters a cavity into which project villus-like processes (fig. 2). This cavity has been interpreted (Luschka;[1] Schmorl[2]) as a rudimentary joint space. However, owing to the greater frequency with which such cavities are found in the disks of older subjects and their common appearance, apparently as an artefact, on dehydration by alcohol during the process of sectioning, we incline to the opinion that these cavities are indicative of an early degree of desiccation of the disk.

1. Luschka, H.: Die Halbgelenke des menschlichen Körpers, Berlin, G. Reimer, 1858.

2. Schmorl, G.: Ueber die an den Wirbelbanscheiben vorkommenden Ausdehnung und Zerreissungsvorgänge und die dadurch an ihnen und der Wirbelspongiosa hervorgerufenen Veränderungen, Verhandl. d. deutsch. path. Gesellsch. **22**:250, 1927.

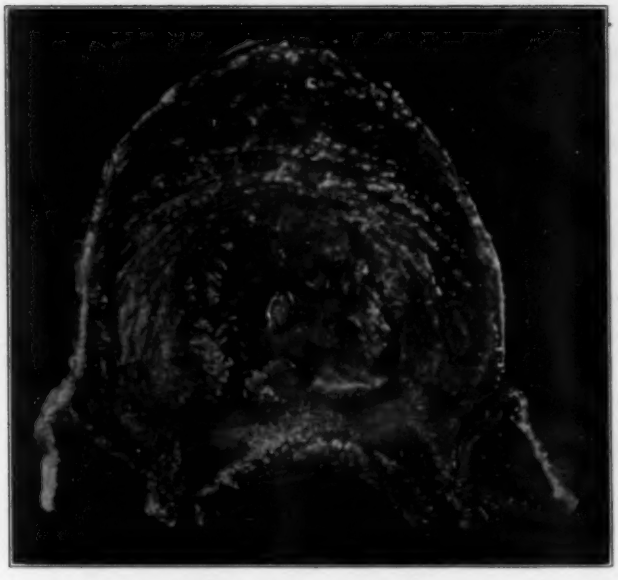

Fig. 2.—Thoracic disk showing a cavity into which project villous-like processes. There is some degeneration in this disk.

Fig. 3.—Microscopic view of an aggregation of notochordal tissue such as is often found in the normal disk. This is a higher magnification of a portion from the central area of figure 1 *B*.

Histologically the nucleus consists of a loose network of delicate fibrous strands with a variable number of cellular elements enmeshed. Centrally the arrangement tends to be highly irregular, or the ground substance may be more homogeneous and relatively structureless. Aggregations of notochordal tissue are most definite in this region (fig. 3). The cells comprising these aggregations are large and occur in clumps of two or three, which are usually well differentiated from the ground substance by condensations of fibrous tissue. The cytoplasm of these cells is abundant and vacuolated. The nucleus tends to lie excentrically and is surrounded by a clear halo, about which the cytoplasm is granular. These are the so-called physaliferous cells of Virchow. Each cell, as well as the cell group, is sometimes surrounded by a concentric sheath of fibrous tissue, recalling the appearance seen in the embryonic notochord. Furthermore, these cells when viewed at low magnification are not unlike cartilage cells, for which they are frequently mistaken, but their roseate grouping is typical. Characteristically a fairly large isolated colony of these cells may be found, above and below, in juxtaposition to the cartilage plate immediately opposite its thinnest central portion. This arrangement not only emphasizes the notochordal origin of these aggregations but suggests that the thinned and somewhat depressed central area of the cartilage plate indicates the point of obliteration of the primitive notochordal canal.

In the more peripheral portion of the nucleus the delicate wavy fibers of connective tissue are more apparent. The cellular elements are few and scattered, consisting of an isolated physaliferous cell or an occasional fibroblast. The transition from nucleus to annulus is gradual and is discernible only by the increasing size of the collagenous fibers. Sections often show centrally large irregular clefts, which may contain cellular debris. We feel that in normal disks these are for the most part artefacts produced during dehydration. From our personal observations we are unable, on either macroscopic or microscopic grounds, to accept the statement that a rudimentary joint space occurs in the normal disk, as contended by Luschka,[1] Schmorl [2] and Smith.[3]

The annulus is composed of heavy collagenous bands, which become coarser as the margins of the disk are approached. The innermost fibers pass into the peripheral edges of the cartilage plate. Those intermediate in position gain attachment to the bone as the fibers of Sharpey, while the most external bundles blend with the adjacent ligaments and fibrous periosteum of the centra. As mentioned, the cellular elements in the neighborhood of the cartilage plates are for the most part cartilage cells oriented in the line of the fibers. Elsewhere mature fusiform fibroblasts predominate.

3. Smith, N. R.: The Intervertebral Discs, Brit. J. Surg. **18**:358, 1931.

PHYSIOLOGIC CONSIDERATIONS

The intervertebral disk plays a most important part in the functional mechanism of the spinal column. Not only does it permit movement to occur between the series of vertebral segments, but it is related to the transmission of body weight, to the absorption and dispersal of the multitudinous shocks to which the column is constantly exposed and to the maintenance of the spinal curves.

The elastic turgor of the disk exerts an expansile force on the opposed vertebral bodies, which is resisted by the various spinal ligaments, thereby establishing a state of internal equilibrium that serves both to resist deforming forces and, when deformity has occurred, to restore the column to the "status quo." This expansile force is due to the compression of the nucleus pulposus within the confines of the annulus and the cartilaginous plates and approximates in the individual disks of the lumbar region some 30 pounds (13.5 Kg.). This estimate was made by Petter [4] on fresh cadavers and on subjects in the supine position. But in the living subject when erect the superincumbent weight of the trunk and upper extremities must raise this pressure in the lower lumbar regions to well over 100 pounds (45.5 Kg.). During transitory phases of spinal movement, as when the back is extended from the flexed position, even with no resistance but that of gravity, estimates would indicate that the pressure may be in excess of 200 or 300 pounds (90.5 or 135 Kg.). That the disk is able to withstand pressure of such magnitude is no doubt related to its high water content. One knows from Pascal's law that liquids transmit in all directions and without diminution any pressure that is applied to them and may for all practical purposes be considered as incompressible. Uebermuth [5] and Püschel [6] studied the water content of the disk, and there appears to be a close correlation between the elasticity of the nucleus pulposus and its water content. Progressive desiccation appears to be a prime factor in senile destruction of the disk and the production of pathologic lesions, for a desiccated disk is an inelastic disk, little able to withstand the compressing forces to which it is constantly subjected. The disks possess a considerable affinity for water. This is simply demonstrated by examining the change which occurs in the disks of a partially dried cadaver after they have been soaked in water for a few minutes. Before immersion the cut surface of the nucleus pulposus shows no

4. Petter, C. K.: Methods of Measuring the Pressure of the Intervertebral Disk, J. Bone & Joint Surg. **15**:365, 1932.

5. Uebermuth, H.: Die Bedeutung der Altersveränderungen der menschlichen Bandscheiben für die Pathologie der Wirbelsäule, Arch. f. klin. Chir. **156**:667, 1929.

6. Püschel, J.: Der Wassergehalt normaler und degenerierter Zwischenwirbelscheiben, Beitr. z. path. Anat. u. z. allg. Path. **84**:123, 1930.

elevation above the plane of section. After immersion there is a remarkable transformation in the nucleus. It rapidly regains its turgor and expands to bulge a quarter of an inch or more above the surface. The annulus, however, shows no more change than do the neighboring paravertebral soft parts.

Püschel's [6] observation would indicate that the water content of normal disks is fairly constant in the same person. It is highest in the newborn and decreases with age, first rapidly and then more slowly. It is higher in the nucleus than in the annulus (80 per cent in the nucleus and 78 per cent in the annulus at birth). The ratio of the water content of the annulus to that of the nucleus remains approximately the same until the fifth decade, when rapid loss occurs in the nucleus, accompanied by various degenerative changes.

Daily variations of water content are suggested by the observations of de Puky.[7] In measuring 1,200 persons between the ages of 5 and 90, he found a daily oscillation in their total heights. These variations amounted to about 1 per cent of the total height, averaging ½ inch (1 cm.) in females and ¾ inch (2 cm.) in males. The younger persons showed a greater fluctuation than did the older ones. Those examined were taller in the morning, on arising, but decreased in stature during the course of the day. These fluctuations are reasonably attributed to compression and loss of turgor in the intervertebral disks.

Numerous investigators have demonstrated that the axis of movement between adjacent vertebrae over a limited range passes through the nucleus pulposus. The substance of the disk is such that any absolute change in its size is exceedingly small. Movement occurs by change in shape. In flexion there is compression of the disk anteriorly and expansion posteriorly, and during extension, anterior elongation and posterior compression. Should extension continue to the point where the spinous processes contact one another, this point of contact becomes the fulcrum and further extension leads to elongation of the entire disk with narrowing of its diameter. This alternating compression and extension of the disk produces displacement of the nucleus pulposus, posteriorly in flexion and anteriorly in extension. In lateral flexion there is slight displacement of the nucleus to the contralateral side.

In addition to the movements described, there are, during flexion, slight forward displacement of each vertebra on the one below and, during extension, slight backward displacement. This movement can readily be seen in lateral roentgenograms by observing the change in

7. de Puky, P.: The Physiological Oscillation of the Length of the Body, Acta orthop. Scandinav. **6**:338, 1935.

alinement of the vertebral bodies and the change in shape of the intervertebral foramen. In the thoracic and cervical regions there are superadded movements of rotation.

These movements, particularly those of a shearing nature, not only are expressed in the morphologic appearance of the disks at various levels, but are of considerable significance in the production of the various types of anterior and posterior fissuring of the annulus, in the pathologic displacements of the nucleus and in the deformities of the spine, such as scoliosis, which attend disk degeneration.

DEVELOPMENT AND MALFORMATION

The intervertebral disks have origin in part from the remnants of the primitive notochord and in part from the mesoderm between the successive blocks of rapidly chondrifying tissue which establish the true vertebral segments. The nucleus pulposus is derived at first from notochord but is extended by a mucoid change which occurs in the surrounding tissue of the so-called notochordal sheath, together with multiplication of the original chordal cells. In the last two or three months before birth there is a dispersal of the cellular groups together with the appearance of fibrocartilaginous elements from the peripherally differentiating annulus. It has been contended in contradistinction to the foregoing statements that the extension of the nucleus is at the expense of the annulus, the chorda cells disappearing completely before birth. We cannot support this contention. We have not infrequently found in adult life notochordal elements enjoying their primitive arrangement within a sheath.

The annulus differentiates later than the nucleus into fibrocartilage. The progressive development and thickening of bundles extend well into the postnatal period. Further postnatal changes are discussed with the pathologic process.

The disk is vascularized during the fetal period. This aspect has been studied in great detail by Boehmig [8] and Uebermuth.[5] The vessels of the disk are divided from those laying down the ossific centers of the vertebral bodies. Six groups, three from either side, are described as piercing the cartilage plates and entering the disk. These vessels, however, undergo progressive postnatal regression and atrophy, a process which leaves behind scars and faults in the cartilage plates (fig. 1 *A*).

In the opinion of these authors such defects are predisposing factors leading to fissuring of the plate and escape of nuclear material. The

8. Boehmig, R.: Die Blutversorgung der Wirbelbandscheiben, das Verhalten des intervertebralen Chordasegments und die Bedeutung beider für die Bandscheibendegeneration, Arch. f. klin. Chir. **158**:374, 1930.

notochordal canal is also of importance in offering an explanation of such herniations. That portion of the notochord passing through the center of the vertebral body is early transformed into a relatively cell-free ligament and, together with its canal, is obliterated during chondrification and ossification of the centrum. It may persist, leave defects or weaken the cartilage plate, allowing the hernias seen in juvenile kyphosis. More complete persistence of the canal, though rare, occurs. Persistence over several segments is most common in the thoracic region and is usually associated with malformation of the vertebral bodies and some degree of kyphosis. The "butterfly" vertebrae of Sereghy [9] have been interpreted on this basis. Beadle [10] recorded examples from the Schmorl collection of persistence of the canal, together with instances of dorsal and lateral displacement of embryonic chordal tissue, which might be interpreted in the light of Minot's [11] work on such displacements as they occur in animals.

Gross malformation of the disks is associated with a wide variety of congenital anomalies of the spine, such as spina bifida anterior, hemivertebrae and the Klippel-Feil syndrome. Complete absence of the disk has been described in the otherwise normal spine. Schmorl and Junghanns [12] pointed out that in examples of what they term *Blockwirbel* they found vertebrae equal in height to two vertebrae together with the disk and that study of such specimens often revealed small remnants of the disk which could not be detected in the roentgenogram. Suppression of the disk from pathologic processes as in figure 4 must be ruled out before making a diagnosis of congenital absence.

GENERAL PATHOLOGIC OBSERVATIONS

Throughout life the intervertebral disks are subject to continuous and progressive changes of structure of a character so marked as to make it difficult to determine what is normal and what is pathologic. Degenerative phenomena are so frequent in supposedly healthy spinal columns at middle age that the changes must be regarded for the most part as the outcome of age processes in an organ subjected to destruc-

9. Sereghy, M.: Eine sonderbare kongenitale Missbildung (Schmetterlingform) der 3. Lumbarwirbels. Ein Beitrag zur Frage der Entwicklung der Wirbelkörper, Fortschr. a. d. Geb. d. Röntgenstrahlen **36**:353, 1927.

10. Beadle, O. A.: The Intervertebral Discs: Observations on Their Normal and Morbid Anatomy in Relation to Certain Spinal Deformities, Medical Research Council, Special Report Series, no. 161, London, His Majesty's Stationery Office, 1931.

11. Minot, C. S.: The Segmental Flexures of the Notochord, Anat. Rec. **1**:42, 1906.

12. Schmorl, G., and Junghanns, J.: Die gesunde und kranke Wirbelsäule im Roentgenbild, Leipzig, Georg Thieme, 1932.

tive forces of considerable magnitude as represented by functional activity. We have already pointed out under physiologic considerations the important observations of Püschel [6] and Uebermuth [5] with regard to the progressive desiccation of the disk with advancing age. The commonest morbid changes found would seem to be related to such desiccation occurring prematurely or to an excessive degree. These

Fig. 4.—Sagittal section of the cervicothoracic portion of the spinal column, showing senile kyphosis. Note particularly the anterior destruction of the disks and the corresponding sclerosis of the adjacent vertebral bony margins. In one instance there has been almost complete replacement of the disk by bone. Otherwise the disks are relatively intact.

changes are by no means equally distributed throughout the spine, nor do they necessarily follow any definite rule. It is our impression, however, that at their inception they are met with more frequently in the midthoracic and lower lumbar regions than elsewhere.

The causal factors in pathologic changes of the disk are often uncertain and whether they are in their initiation physiologic degenerative, traumatic or inflammatory, they are for the most part not very dissimilar in nature, varying perhaps mostly in the degree of repair shown by such a relatively avascular structure. Whereas it should be firmly kept in mind that the unit comprising the disk consists of an annulus, a nucleus and cartilage plates, functionally depending on all elements remaining intact, we have found it convenient from a descriptive point of view to consider the pathologic appearance of these elements seriatim.

The cartilage plates, enclosing the nucleus, would seem to constitute the part of the disk most resistant to degenerative phenomena. They are, however of the greatest importance, in that solution in their continuity allows escape of nuclear material with consequent loss in elasticity and degeneration of the disk as a whole. This has been shown experimentally to occur in dogs, monkeys and rabbits (Keyes and Compere;[13] Tammann;[14] Filippi[15]). The changes in the cartilage plates may be primary or secondary to degeneration of the disk or to disease within the bony vertebral body.

In discussing the normal histologic appearance of the plate it was pointed out that its central portion is often depressed and thinner than the remainder. We offered our opinion that this defect corresponded to the point of closure of the primitive notochordal canal. Either through persistence or through incomplete closure of the notochordal canal or secondary breakdown of the point of closure, nuclear material may be extruded into the spongiosa of the vertebral body, establishing the so-called *Knorpelknötchen* of Schmorl. Such defects as found in young subjects are readily recognized (fig. 5). The intraspongious hernias are characteristically arranged one above the other through several segments. Histologically the gap in the cartilage plate is apparent and is usually fairly small, with little or no displacement of the margins as seen in traumatic rupture of the plate. The herniated material is obviously nuclear and often, especially in older specimens, shows at its periphery transformation into cartilage or pseudocartilage. The surrounding spongiosa tends to be thickened, walling off the hernia from the marrow spaces (fig. 6). The subjoined disk is thinned but

13. Keyes, D., and Compere, E.: The Normal and Pathological Physiology of the Nucleus Pulposus of the Intervertebral Discs, J. Bone & Joint Surg. **14**:897, 1932.

14. Tammann, H.: Ueber die Wundheilung im Bereich der Zwischenwirbelscheibe, Arch. f. orthop. u. Unfall-Chir. **34**:356, 1934.

15. Filippi, A.: La guarigione del disco intervertebrale dopo asportazione del nucleus pulposus negli animali da esterimento, Chir. d. org. di movimento **[20]**:1, 1935.

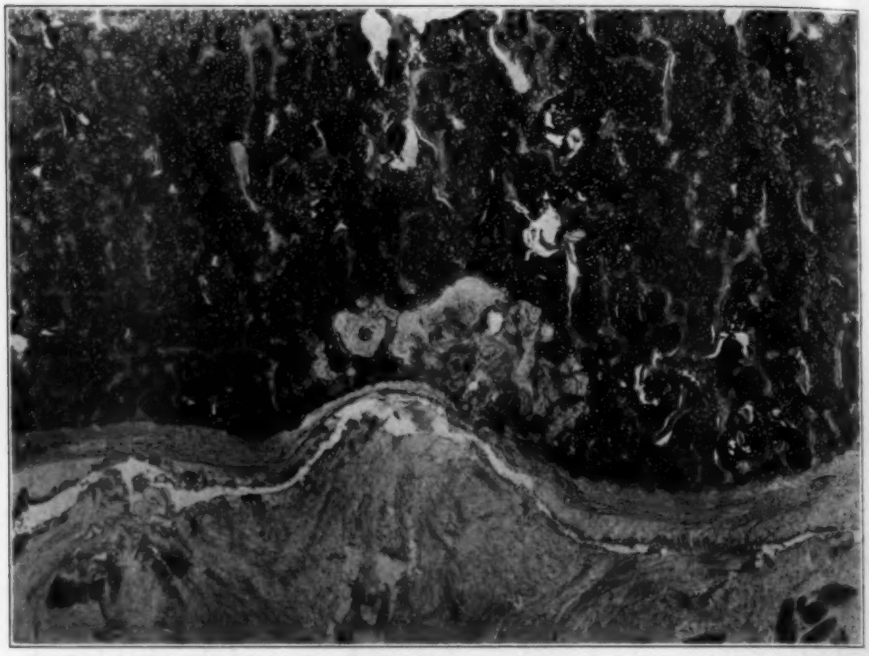

Fig. 5.—Intraspongious hernia of nuclear material through small defect in the cartilage plate. The racemose-like form is characteristic of many of these hernias. There is little peripheral reaction.

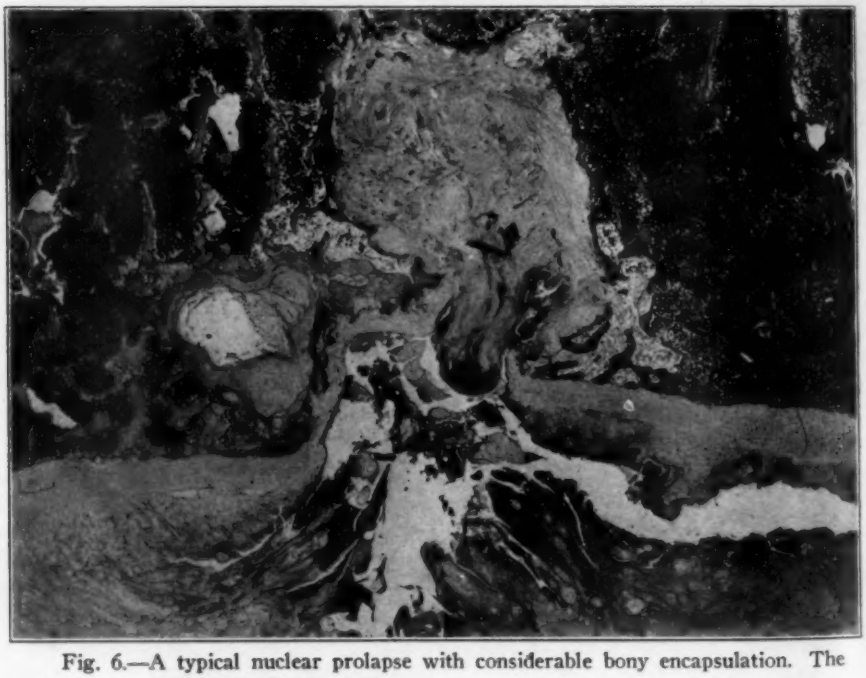

Fig. 6.—A typical nuclear prolapse with considerable bony encapsulation. The rent in the cartilage is clearly seen.

relatively intact at first, exhibiting little degeneration. Although we have not had the opportunity to examine many spinal columns of this type because of the difficulty of obtaining material from young subjects not suffering from a lethal condition, we are convinced from roentgen evidence that attendant degeneration of the disk sets in early and is often well established by the second decade. The significance of such herniations in the production of juvenile kyphosis will be discussed in a further section of the paper. However, changes which we take to be preliminary to the rupture of cartilage in youth may be

Fig. 7.—Protrusion of cartilage plate with small areas of fibrillation.

seen in some specimens otherwise exhibiting a typical series of hernias. These changes occur at the summit of the aforementioned depressions in the cartilage plates and consist of a small area in which the cartilage cells are absent and replaced by fibrillated material (fig. 7). We are uncertain as to whether to interpret these areas as scar formation or as evidence of the giving way of the cartilage plate at a point of weakness.

Not infrequently we have found a series of radiating fissures in the central part of the plate. These fissures are filled, on gross inspection, with a translucent material (fig. 1 *A*), which histologically appears to be a relatively structureless cicatrix. In the opinion of Böhmig [8] and Uebermuth [5] the fissures were formerly occupied by the vessels

which supplied the disk during development, which have undergone obliteration, and may be the starting point of the nuclear herniations of youth.

Their great frequency in the cartilage plates of older specimens suggests, however, that they may, on the other hand, be of degenerative origin.

Traumatic rupture of the cartilage plate occurs in conjunction with compression fracture of the vertebral body, but it has been remarked how often the disk escapes injury even in the most severe lesions. In these circumstances the nuclear material is widely dispersed in the spongiosa and after healing is partially absorbed and partly isolated by condensation of the surrounding spongiosa. The disk itself is markedly thinned and undergoes vascularization with fibrosis or even partial bony replacement in the later stages. An important variety of trauma to the cartilage plate is that associated with marginal fracture of the vertebral body. These chip fractures are commonly anterior in position and are in themselves insignificant but, from roentgen evidence, are followed by collapse and thinning of the disk. It would seem that the involvement of the disk is due to the extension of the fissure into the cartilage plate with attendant loss of nuclear substance and degeneration of the disk (Hanson;[16] Janker;[17] Joisten;[18] Junghanns;[19] Mikhailoff and Tcherepnin[20]).

Rupture of the cartilage plate occurs secondary to loss of support by the spongiosa of the vertebral body. The commonest form is that associated with senile osteoporosis of the spine. The turgor of the nucleus balloons out almost the entire extent of the plates so that the disk acquires a highly biconvex form and the vertebral body intervening between two such disks becomes amphicelous. The most exaggerated examples are found in the lumbar region, where the disks are bulky. The cartilage plate exhibits fissures and breaks in continuity, and the herniation of nuclear material is usually massive, with little surrounding reaction. The remainder of the disk is relatively healthy.

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16. Hanson, R.: Some Anomalies, Deformities and Diseased Conditions of the Vertebrae During Their Different Stages of Development, Elucidated by Anatomical and Radiological Findings, Acta chir. Scandinav. **60**:309, 1926.

17. Janker, R.: Die Epiphysen der Wirbelkörper und ihre Veränderungen "Persistierende Wirbelkörperepiphysen," Fortschr. a. d. Geb. d. Röntgenstrahlen **41**:597, 1930.

18. Joisten, C.: Ueber persistierende Apophysen an der Lendenwirbelsäule, Arch. f. Orthop. **28**:622, 1930.

19. Junghanns, H.: Gibt es "persistierende Wirbelkörperepiphysen"? Fortschr. a. d. Geb. d. Röntgenstrahlen **42**:704, 1930.

20. Mikhailoff, M., and Tcherepnin, M. I.: Ueber die Wirbelknorpelinseln und deren Röntgenbild, Fortschr. a. d. Geb. d. Röntgenstrahlen **40**:1061, 1929.

Similar rupture of the cartilage plate follows loss of bony support due to invasion of the vertebral body by infection or tumor (fig. 8).

The cartilage plate does not escape in the general process of degeneration of the disk found with advancing age. In senile osteoporosis, as discussed in a foregoing paragraph, the rest of the disk is fairly normal in character, and, in addition, the rupture is usually single. The degree of involvement of the cartilage plate in degeneration of the disk varies considerably. In some specimens the changes elsewhere may be advanced and the cartilage plates relatively intact. In others the changes in the plate are extensive. It is not uncommon to find, on gross examination, multiple large jagged fissures (fig. 9). Histologically, numerous patches are found where the cartilage matrix is frayed and replaced by a poor fibrous scar, which may extend partially or entirely through the thickness of the plate. Erosion in multiple areas by the ingrowth of granulation tissue from the marrow spaces is common and when extensive is accompanied by marked vascularization and fibrosis of the disk. The original plate may be represented by small islands of cartilage only, a compact scar or area of ossification replacing it. Under these circumstances the herniations of nuclear material into the spongiosa are small, irregular and not so centrally localized as in other forms. As to the interpretation of these changes, it is difficult if not impossible to say whether the damage to the cartilage plate is the result of the numerous small traumas of daily life acting on developmentally faulty cartilage plates with secondary degeneration of the disk, as contended by some, or whether the cartilage simply participates in the general senile decay of the disk.

The nucleus pulposus varies considerably in structure from infancy to old age. In infancy the nucleus is well defined, and its line of demarcation from the annulus is distinctive. Histologically it consists of a fairly loose network of cells of primitive mesenchymal type and physaliferous cells of Virchow. By the second decade the transition from nucleus to annulus is much less definite. The cells are fewer, and the delicate fibrous processes, as described under normal histologic aspects, are more apparent. In the middle decades, normally the fibrous elements are still more definite, and the disk is more homogeneous. At this stage cavities in the central zone are frequent, and villous processes are in evidence. These cavities contain a gelatinous fluid and, on microscopic examination, some cell debris. Nests of cartilage cells are found scattered throughout the nucleus, and in the subchondral region there is some transformation into organized fibrocartilage. Thereafter the disk undergoes progressive dehydration and fibrosis.

It should be borne in mind that there is a progressive change in nuclear architecture from decade to decade. Pathologic conditions must be interpreted in the light of such progressive changes.

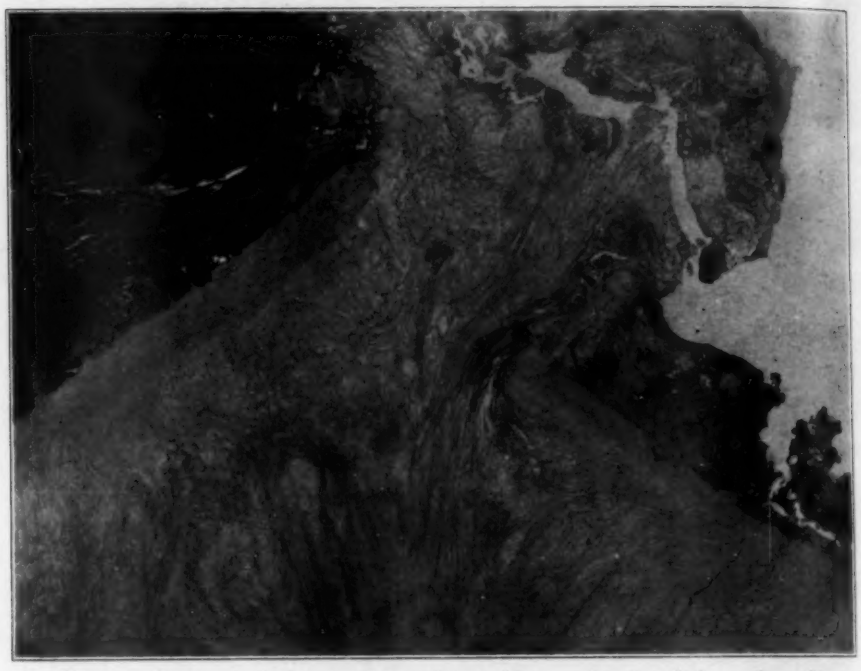

Fig. 8.—Rupture of the cartilage plate with massive herniation of nuclear material, associated with metastatic carcinoma. There is slight invasion of the nuclear substance; this is, however, unusual.

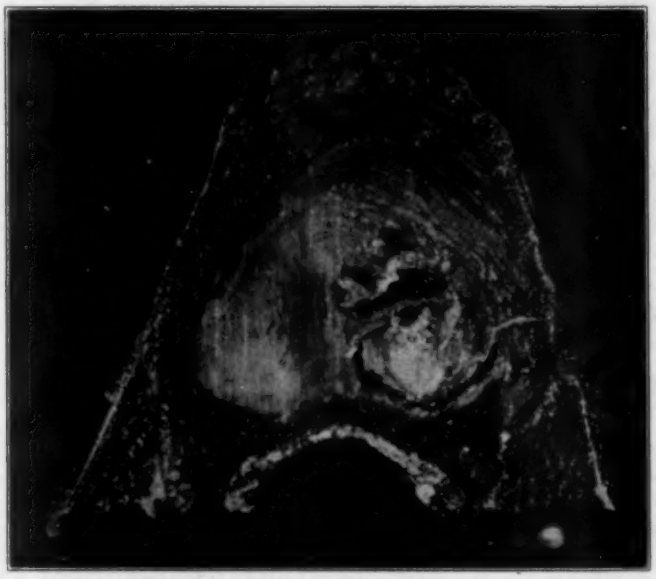

Fig. 9.—Large jagged tear in the cartilage plate of a degenerated disk.

Fig. 10.—Exaggeration of the nucleus and nuclear cavitation as seen in a lumbar disk.

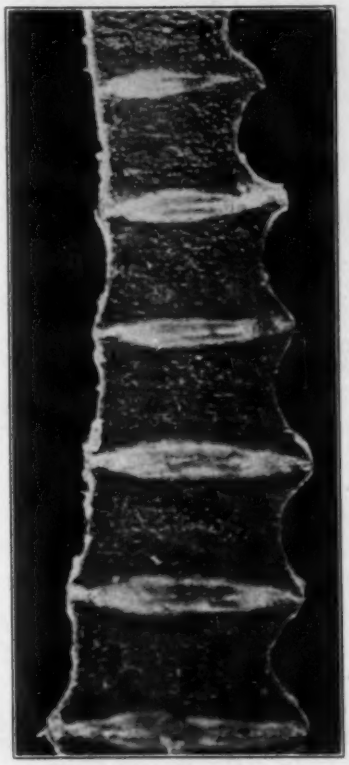

Fig. 11.—Coronal section of the thoracolumbar portion of the spinal column. Note the parallel areas of "brown degeneration" in the subchondral zone and collapse of the disks.

Degeneration may occur as early as the third decade or before if the integrity of the disk has been interfered with by trauma or congenital defects in the restraining cartilage plates. Grossly the earliest change would seem to be an exaggeration in the size of the nucleus and an excessive extent and development of nuclear cavitation (fig. 10). Such disks appear to be deficient in turgor and elasticity. Further development would seem to be in the breakdown of the fibrillary structure and the dissolution of the cellular elements, until the whole nucleus is reduced to an amorphous mushy mass which consists of cell debris–necrosis. In this mass quite rarely calcium salts are deposited.

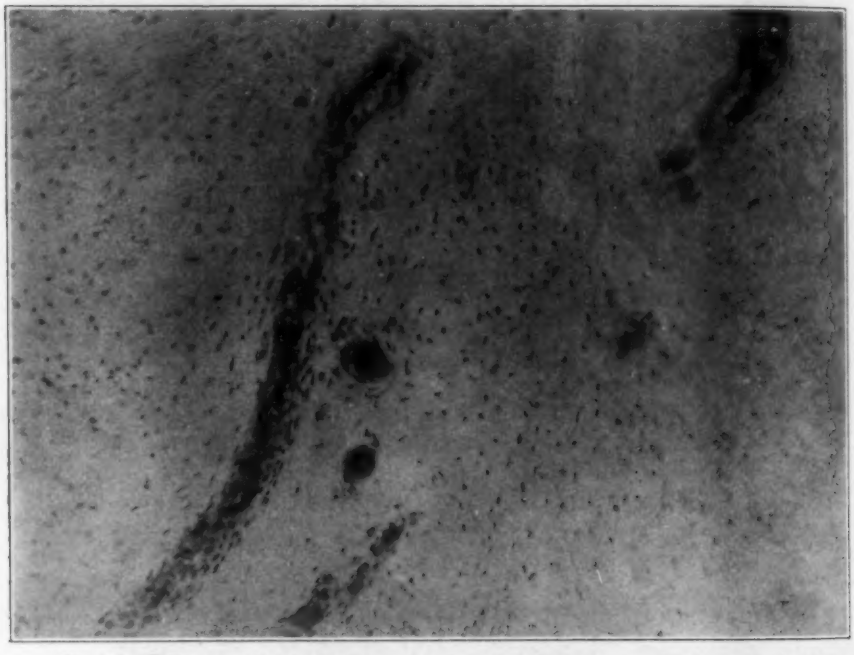

Fig. 12.—Microscopic view of the annulus showing commencing vascularization and fibrosis.

By this time, minor defects and erosions of the confining cartilage plates have appeared, which may rupture and lead to the escape of nuclear material. On the other hand, areas of so-called "brown degeneration" appear beneath the cartilage plates (fig. 11) and seem to be the result of hemorrhage from fine vascular tufts which have invaded the disk through the cartilage plates. From loss of turgor, the disk has usually by this time undergone almost complete collapse.

Various stages of repair may ensue, consisting initially of an increase of fibrous and cartilaginous elements, tending to replace the nuclear

material. This may proceed to a point where the disk by further vascularization is partially or completely replaced by bone (fig. 4).

Extruded nuclear material shows a marked tendency to become transformed at its periphery into cartilage or pseudocartilage, and the

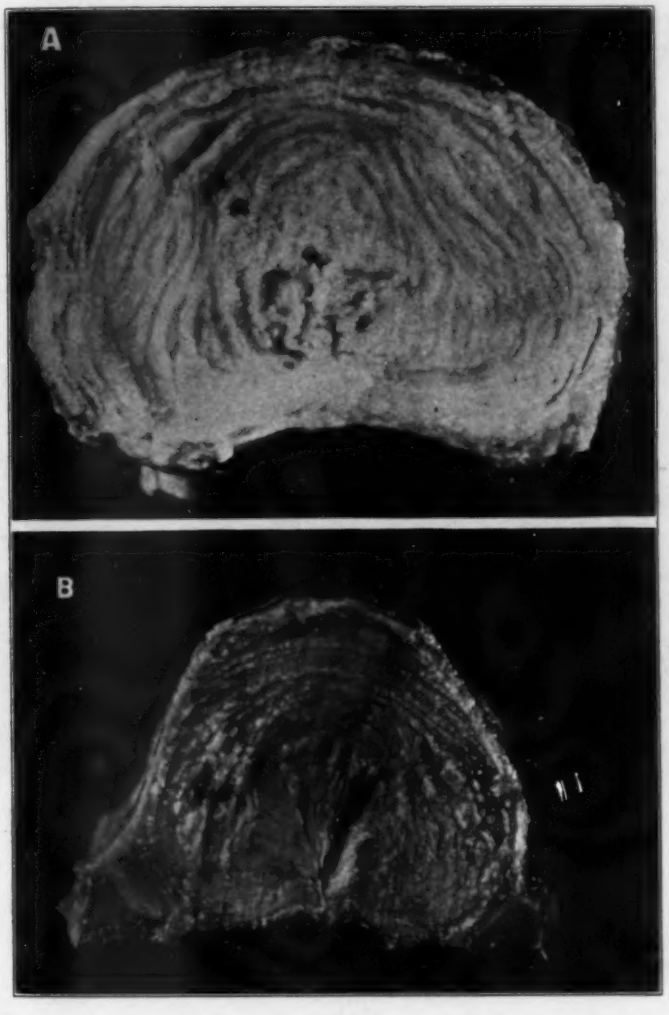

Fig. 13.—*A*, disk showing anterior crescentic fissures in the annulus. *B*, dorsal radial fissure with slight escape of nuclear material.

process may go on to ossification. More central portions tend to show an increase in the number of cartilage cells or to become transformed into fibrous tissue when there is evidence of vascularization.

The annulus fibrosus likewise shows progressive changes during its life history. With increasing age the fibrous lamellae become more

and more definite and larger. With the onset of degeneration the inner layers merge into the expanding nucleus until little more than a ring of the original tissue persists (fig. 10). During this process the lamellae become more swollen, some areas show necrosis, and vascularization commences (fig. 12). The fibrous bundles may separate, producing concentric fissures, some of which may extend through the entire thickness in a radial direction. The concentric fissures are most frequent anteriorly (fig. 13*A*) and occur most characteristically in kyphosis of old age.

Fig. 14.—"Brown degeneration" extending in crescentic fashion between the bundles of the annulus.

The radial fissures are most often found dorsally (fig. 13*B*), and through them nuclear material may herniate into the vertebral canal. Necrosis is far less common in the annulus than in the nucleus and is more often found anteriorly. In conjunction with necrosis, small areas of calcification are found, and these may lead to formation of isolated bony deposits if these areas are adequately vascularized. As in the nucleus, areas of so-called "brown degeneration" may be found, and these areas tend to lie crescentrically between the bundles of the annulus (fig. 14). In our opinion they are the result of hemorrhage from delicate vascular channels. With the collapse of the disk, the annulus as a whole tends to be displaced peripherally and bulges in all directions.

The annulus may show evidence of attempts at repair. Initially, notably in the lumbar region, it may take on an exaggerated fibrocartilaginous appearance. With the increasing vascularization, the fibrous cellular elements are greatly increased. The change at the peripheral zone of junction with the vertebral body is a special feature. Here, hyperplasia of the fibrocartilage tends to increase the thickness

Fig. 15.—Coronal section of the thoracolumbar portion of the spinal column, showing marked dissolution and collapse of the intervertebral disks, lateral displacement of the vertebrae and osteophyte formation.

of the annulus, and its vascularization is attended by the formation of osteophytes. We feel that the formation of osteophytes does not occur in the original annulus material but in the superadded tissue which is developed as a repair mechanism in response to the increasing strain thrown on the peripheral junction by the progressive collapse of the disk and the development of shearing forces set up in the lateral dis-

placements of the vertebral segments as in the scoliosis of arthritis deformans (fig. 15).

Posterior Displacements.—Dorsal protrusions, displacements or herniations of disk tissue merit separate consideration because of their special significance in causing pressure on the contents of the neural canal.

Fig. 16.—Sagittal section of the cervical portion of the spine, showing fairly large protrusion and herniation of the fourth, fifth and sixth cervical disks. There is some indentation of the spinal medulla.

Extradural tumors, variously termed chondromas, fibromas, fibrochondromas, chondrochordomas, exostoses and ecchondroses, have long been described as occurring most frequently in the lumbar and cervical regions. These so-called tumors are now clearly recognized as being due to displacement of disk tissue dorsally.

From the pathologic point of view, posterior displacements of the disk tissue are formed with the greatest frequency in the spinal columns of elderly persons. Andrae [21] reported finding cartilaginous nodules on the dorsal aspects of 15 per cent of 368 columns examined. They are found most frequently in the lower thoracic and lumbar regions and are nearly always attended by definite evidence of disk degeneration. The thoracic protrusions tend to be small and insignificant, often buried beneath the posterior longitudinal ligament. In the lumbar and cervical regions they are larger and frequently extend to one or other side of the midline (fig. 16).

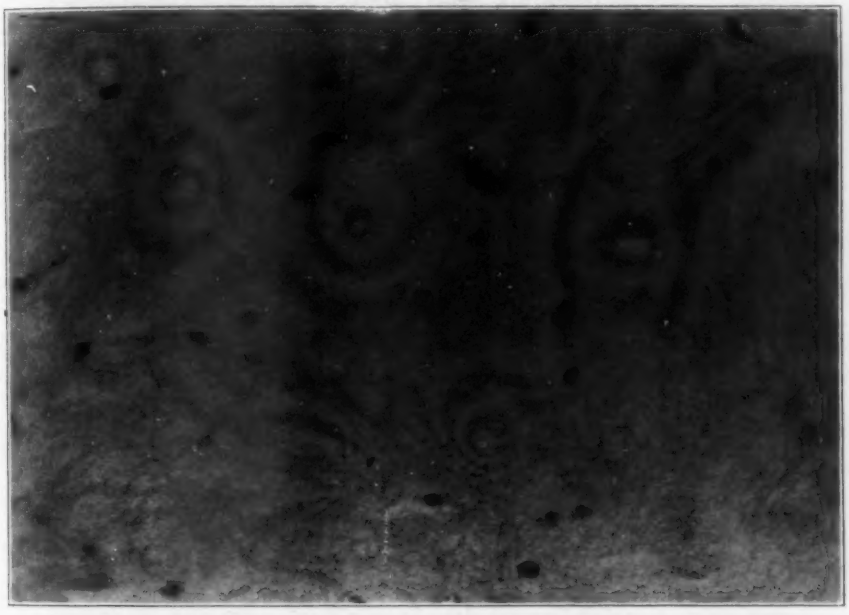

Fig. 17.—Characteristic nuclear material removed operatively from a dorsal herniation.

Histologically the material obtained post mortem or at operation presents an extremely variable picture. In some specimens the structure is characteristically that of the nucleus pulposus, although as a rule the cellular elements are increased and there is true inflammatory reaction (fig. 17). In others, and perhaps the great majority, there is a mixture of pulposal and annular material showing a varying degree of cartilaginous metaplasia, inflammatory reaction or necrosis. We have observed in a specimen a portion of the confining cartilage plate

21. Andrae, R.: Ueber Knorpelknötchen am hinteren Ende der Wirbelbandscheiben im Bereich des Spinalkanal, Beitr. z. path. Anat. u. z. allg. Path. **82**:464, 1929.

in the protruded tissue. Those of long standing, and therefore obtained on postmortem examination, show a great abundance of cartilaginous transformation with areas of calcification and after-vascularization, even of bone.

Some discussion has arisen as to whether these nodules are herniations of nuclei pulposi or protrusions of intervertebral disks. In our opinion both varieties may be found. In some cases we have seen fissuring of the annulus surrounded by "brown degeneration" with herniation of nuclear material. In others we have found collapse of the disk and protrusion of the annulus with or without herniation of the nucleus. These findings are nearly always attended by profound disk degeneration. In regard to younger subjects with otherwise healthy disks the question arises as to whether trauma is not the main causal agent. We doubt that in such subjects trauma would rupture the annulus; it would be more likely to fissure the cartilage plate at the junction with the annulus, and the finding of a portion of the plate in the extruded material is suggestive of this mechanism.

We should like to emphasize that posterior herniations are in the great majority of instances evidence of general disk degeneration.

PATHOLOGIC OBSERVATIONS IN SPECIAL CONDITIONS

Infections and Tumors.—The disks seldom appear to be involved either primarily or secondarily in disease processes, whether these are infectious or malignant. The cartilage plates, like the epiphysial plates of long bones, are apparently extraordinarily resistant to invasion. In the more acute destructive processes, e. g., staphylococcic osteomyelitis, the disk may undergo necrosis and be completely destroyed. In the less destructive, there may be erosion of the cartilage plate with ingrowth of granulation tissue and scarring of the disk. It is said that in other forms of spondylitis, as in typhoid spine, the disks escape.

Tuberculosis is notable in that the disk is nearly always involved secondarily. We have noted multiple erosions of the cartilage plate by granulation tissue in the early stages and minute ruptures with escape of nuclear material into the spongiosa. Eventually the disk is partially destroyed and is replaced by bone in healing or is displaced during the stage of collapse.

The disks may be involved in syphilitic spondylitis and in the late stages of syphilitic osteoarthropathy as well as in syringomyelia.

The disks are even more resistant to invasion by tumors. In the presence of tumors with associated osteolysis the disks tend to bulge into the spongiosa but not nearly to the same extent as in senile osteoporosis. Loss of support to the cartilage plates frequently leads to their rupture, with massive herniation of nuclear material into the spongiosa (fig. 8).

Primary tumors of the disk or of its derivatives, the chondromas, are rare and scarcely warrant discussion here.

Adolescent Kyphosis.—Clinically, adolescent kyphosis is a well defined condition, displaying typically the following characteristics: It is reported to occur in males more frequently than in females, although in our opinion this difference in incidence is more apparent than real. The deformity is essentially a rigid rounded kyphos, centered usually between the seventh and tenth thoracic vertebrae, and in less than half the cases there are associated unimportant lateral curves. The kyphos is rarely discernible before the age of 10; the onset is most frequent between the ages of 15 and 17 years. The patients are nearly always rapidly growing healthy persons with excellent musculature. Pain is an inconstant complaint and is usually in the nature of an ache on exertion.

The roentgen appearance of the involved vertebrae is distinctive. The changes are first seen in the subchondral bone adjacent to the intervertebral disk and are better observed in lateral than in anteroposterior projections.

The first deviation from the normal appearance is an irregularity of the subchondral bone at the superior and inferior surfaces of the vertebral bodies. These surfaces, instead of appearing as a thin smooth continuous distinct line in the roentgenograms, become irregular and broken. The intervertebral disk is always narrowed. In the vast majority of cases sizable herniations of the nuclear material into the spongiosa are indicated by sclerosis of the adjacent bones. These herniations vary in size, number and position. In older lesions the abnormal transmission of weight from vertebra to vertebra in the region of the kyphos leads to wedging of the vertebral bodies, sclerosis of the anterior portions of the superior and inferior surfaces of the vertebrae and osteophyte formation. We have noted that in the cases of adolescent kyphosis which show early the most marked changes in the subchondral bone there is often associated a definite platyspondylia of the involved vertebra.

The cause of this condition is still obscure. Several hypotheses have been advanced by various authors. Schanz [22] and his pupil Elsner [23] expressed the opinion that the condition was related to the effects of heavy work on a growing spine. Eichelbaum [24] suggested

22. Schanz, A.: Eine typische Erkrankung der Wirbelsäule (Insufficienta Vertebrae), Berl. klin. Wchnschr. **44**:986, 1907.

23. Elsner, J.: Ueber Lehrlingsskoliose, Ztschr. f. orthop. Chir. **32**:277, 1913.

24. Eichelbaum, K.: Ergänzende Bemerkung zur Arbeit Schildbach: "Die Entwicklung der juvenilen Kyphose," Zentralbl. f. Chir. **64**:2894, 1937.

muscular insufficiency as the primary cause. Scheuermann [25] regarded the disease as an epiphysitis and termed it osteochondritis deformans juvenilis dorsi. Schmorl [26] advanced the strongest evidence to show that the kyphosis is the direct result of alterations in the intervertebral disks, a view which has received considerable support (Calvé; [27] Beadle [10]). He demonstrated by postmortem evidence that prolapse of the nucleus pulposus into the spongiosa of the vertebral bodies may occur, even in children, as the result of congenital weakness or defect of the cartilage plates. The histologic appearance of these protrusions has already been discussed under general pathologic observations. Disturbances of the cushioning effect of the nucleus in overloading and trauma lead to secondary changes in the epiphyses and bodies of the vertebrae. Roentgenologically the presence of such hernias cannot always be discovered, which is explained as being due to the absence of reactive changes in the bone, for it is not the prolapse but the sclerosis of bone about the prolapse which renders Schmorl's *Knorpelnötchen* visible. It is true that in many cases these notches become evident only in the later stages of the disease. Schmorl's theory has not been without criticism even by its supporters.

Schmorl,[28] in criticizing Scheuermann's conception that the condition is epiphysitis, put forward the extraordinary view that the epiphysis of the vertebra is in no way analogous to the growth epiphysis seen elsewhere and that it has nothing to do with growth processes. He would regard the epiphysis as in the nature of a mechanism giving eventual bony fixation to the annulus. We find this view totally unnecessary to Schmorl's thesis, and it is certainly not borne out by the experimental

25. Scheuermann, H.: Kyphosis dorsalis juvenilis, Ztschr. f. orthop. Chir. **41**: 305, 1921; Cyphose juvénile, Arch. méd. belges **81**:353, 1928; Zur Roentgensymptomatologie der juvenilen Osteochondritis dorsii, Fortschr. a. d. Geb. d. Röntgenstrahlen **44**:233, 1931; Roentgenologic Studies of the Origin and Development of Juvenile Kyphosis, Together with Some Investigations Concerning the Vertebral Epiphyses in Man and in Animals, Acta orthop. Scandinav. **5**:161, 1934.

26. Schmorl, G.: Die Pathogenese der juvenilen Kyphose, Fortschr. a. d. Geb. d. Röntgenstrahlen **41**:359, 1930; Bemerkungen zu der Arbeit von Mau zur Frage der Pathogenese beziehungsweise der pathologischen Anatomie der Adoleszentenkyphose, Ztschr. f. orthop. Chir. **55**:274, 1931; Ueber die pathologische Anatomie der Wirbelbandscheiben, Beitr. z. klin. Chir. **151**:360, 1931.

27. Calvé, J.: Ostéo-chondrite vertébrale infantile, Bull. Soc. pédiat. de Paris **25**:489, 1927; Ostéo-chondrite vertébrale infantile, in The Robert Jones Birthday Volume: A Collection of Surgical Essays, London, Oxford University Press, 1928, p. 315.

28. Schmorl, G.: Zur Kenntnis der Wirbelkörperepiphyse und der an ihr vorkommenden Verletzungen, Arch. f. klin. Chir. **153**:35, 1928; Zur Sektionstechnik der Wirbelsäule, Zentralbl. f. allg. Path. u. path. Anat. **47**:7, 1930. Schmorl and Junghanns.[12]

work of Haas [29] or by clinical observation, as is seen in fusion of the spine in children. Growth from this epiphysis is very slow and is extended over many years, which accounts for its histologic appearances, which lack the usual columnar formation.

Senile Kyphosis.—Senile kyphosis has been recognized for many years and grouped in a somewhat confused manner with the deforming conditions of old age. Schmorl,[30] recognizing the primary changes as a special type of destruction of the disk, segregated senile kyphosis as a distinct entity. The characteristic feature of this condition is the spinal curvature, which appears usually late in life and develops rapidly as an exaggeration of the physiologic thoracic curve. The curvature is most marked in the upper thoracic part of the spine and may progress to a high degree.

Roentgenologic and pathologic studies of senile kyphosis reveal the following progression of events. With commencing kyphosis there is narrowing of the intervertebral disk anteriorly together with increasing sclerosis of the anterior borders of the vertebral bodies. There may be some degree of osteophyte formation, but usually it is not marked. The anterior compression of the disk continues until the vertebral bodies contact each other at their anterior borders. The intervening disk tissue is destroyed and replaced by bone, and thus the involved vertebral bodies are fused anteriorly with a continuous bridge of bone. The posterior portions of the intervertebral disks usually show a fair degree of preservation (fig. 4).

Postmortem studies on senile kyphosis indicate that the essential pathologic process is pressure necrosis of the anterior portion of the intervertebral disk. The abnormal pressure on the anterior portion of the disk, leading to its necrosis, results from general loss of muscular tone in the aged and the failure of the senile inelastic disk to disperse adequately the compression forces applied to it. The vertebral bodies do not become wedge shaped to any great degree in senile kyphosis inasmuch as the anterior narrowing of the disk is sufficient to account for the deformity.

Spondylosis Deformans.—The conception that spondylosis deformans is the outcome of degeneration of the intervertebral disks is now generally accepted by most investigators in this field. The fundamental lesion is the change in the intervertebral disk leading to its progressive deterioration and functional failure. The pathologic

29. Haas, S. L.: Growth in Length of the Vertebrae, Arch. Surg. **38**:245 (Feb.) 1939.

30. Schmorl, G.: Zur pathologischen Anatomie der Wirbelsäule, Klin. Wchnschr. **8**:1243, 1929; Ueber die pathologische Anatomie der Wirbelbandscheiben, Beitr. z. klin. Chir. **151**:360, 1931; Beiträge zur pathologischen Anatomie der Wirbelbandscheiben und ihre Beziehungen zu den Wirbelkörpern, Arch. f. orthop. u. Unfall-Chir. **29**:389, 1931. Schmorl and Junghanns.[12]

processes seen in the spinal column as dependent on degeneration of the disks may not necessarily be related to the age of the patient. Spondylosis deformans may appear as early as the third decade of life. It affects every one if sufficient time elapses. The frequency naturally increases with age and approaches 100 per cent at the age of 90 years (Schmorl and Junghanns[12]). The disks, through age or individual predisposition, lose elasticity and, under the influence of continuous functional trauma, pass through the various stages of degeneration: fibrillary degeneration, brown degeneration, cartilage plate rupture, nuclear prolapse, necrosis, fissuring, hemorrhage, vascularization and reactive changes.

In spondylosis deformans disk degeneration is usually generalized throughout the spinal column (fig. 15). There is dissolution with loss of substance in the nucleus pulposus, followed by relaxation and protrusion of the annulus about the periphery. This leads to lateral shifting of the vertebral bodies. The loss of turgor of the nucleus permits increased mobility between the segments with strain on the ligamentous structures and formation of osteophytes. Osteophytes tend to occur adjacent to the spinal ligaments and appear earliest in those areas of the spinal column that are subjected to the greatest movements. Nonappearance of osteophytes posteriorly may be accounted for by the fact that movement between the vertebral bodies is less posteriorly than anteriorly.

Ankylosing Spondylitis.—Ankylosing spondylitis is considered by the more recent observers as rheumatoid arthritis involving primarily the small articulations of the spinal column. There follows smooth ossification of the anterior longitudinal ligament and of the outer layers of the annulus without formation of osteophytes. The disks disappear to a greater or lesser extent and are replaced by bone.

Investigations in our clinic (Rinehart and associates[31]) indicate a relationship of vitamin C to all forms of rheumatoid arthritis and particularly to ankylosing spondylitis.

Mr. Leonard Taix and Mr. Robert Ray made the photographs.

31. Rinehart, J. F.; Greenberg, L. D.; Baker, F.; Mettier, S. R.; Bruckman, F., and Choy, F.: Metabolism of Vitamin C in Rheumatoid Arthritis. Arch. Int. Med. 61:537 (April) 1938.

COMPRESSION OF SPINAL CORD AND NERVE ROOTS BY HERNIATION OF THE NUCLEUS PULPOSUS IN THE CERVICAL REGION

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In 1927 there was brought together for the first time, as representing a clinical entity, a group of unusual "tumors" arising from the cervical intervertebral disks (Stookey). Scattered reports of such lesions had appeared previously, notably Adson's report of a case and a mention of one by Elsberg in his "Tumors of the Spinal Cord." The condition, however, was not generally recognized as distinct from other vertebral tumors, and no reference to it is to be found in such standard texts as those of Elsberg, Bruns, Schlesinger, Lubarsch and Ostertag and Antoni.

On the basis of the histologic picture and because at the time no other explanation of the tumor-like masses seemed plausible, they were regarded as chondromatous new growths and were designated ventral extradural cervical chondromas. The extensive studies of Schmorl (1929) and Andrae (1929) on the spinal column and their elucidation of the nature and structure of the nucleus pulposus have since led to a revision of this view and it now seems evident that the lesions are not neoplastic but represent rather herniation or protrusion of the nucleus pulposus through the annulus fibrosus, sometimes with secondary changes, such as calcification. True chondromas may indeed be found but are certainly far less common than herniated disks.

Following the publication of my original paper, numerous reports of protrusion of intervertebral disks appeared, including those of Dandy, Bucy, Alajouanine and Petit-Dutaillis, von Péchy, Elsberg, Antoni, Mixter and Barr, May, Alpers, Grant and Yaskin and others. Mixter and Ayer reported a series of 34 cases of vertebral herniation, in 8 of which the protrusion was in the cervical region. Hawk in 1936 collected from the literature 16 cases of protrusion of cervical disks and reported 1 new example.

The ventral extradural cervical herniated disk is a discrete, sharply circumscribed mass, seldom exceeding 1.5 cm. by 1 cm., consisting of thin layers of frayed cartilaginous tissue, which are readily separated. It lies in front of the dural sac, in or to one side of the midline. Unlike the large paravertebral new growth, which invades the spine secondarily,

the herniated mass arises within the vertebral canal. It is found for the most part in relation to the freely movable vertebrae of the mid-cervical region, an area especially liable to repeated minor strain and stress but seldom the site of sudden severe trauma, such as occurs in the lumbar region as a result of heavy lifting or of a fall on the buttocks.

A history of sudden onset associated with injury is thus rarely obtained in herniations of the cervical region. It seems likely that the cervical protrusion is primarily a degenerative lesion associated with repeated traumas of minor degree. As a result of such traumas or in the course of the degenerative process, a slight fissure occurs in the posterior portion of the annulus, through which the nuclear mass protrudes. Judging from the clinical histories, the protrusions in the cervical region occur gradually and are seldom sudden or violent. In

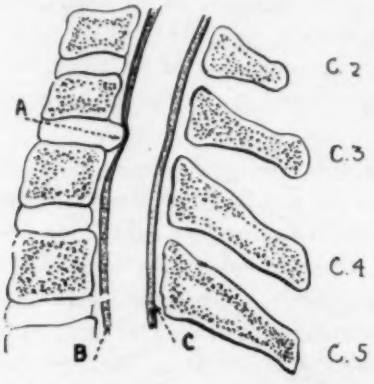

Fig. 1.—Schematic drawing showing extradural ventral protrusion of the nucleus pulposus. *A* indicates protrusion of the nucleus pulposus; *B*, spinal fluid buffer; *C*, dura. (From Stookey, 1928.)

the latter case, since protrusions in this region impinge, as a rule, on the spinal cord and not on the nerve roots, as in the lumbar region, signs referable to the cord would at once be evident, for sudden trauma to the spinal cord is far more likely to give rise to obvious clinical signs than similar trauma to nerve roots. The onset of symptoms of a cervical protrusion, however, is usually gradual and slowly progressive.

INCIDENCE

Both Schmorl and Andrae noted that while protrusion in the lumbar region is of frequent occurrence, protrusion in the cervical region is rare. This is borne out by a study of the literature. Since the recognition of cervical protrusion as a definite clinical entity, in 1928, relatively few examples have been recorded, whereas the study of cases of herniation in the lumbar region by Mixter and Barr was followed by a

large number of reports, notably those of Adson and Craig and Love, from the extensive material of the Mayo Clinic, Spurling, and Semmes.

The majority of cervical disk herniations occur in men of late middle age. The youngest of my patients was 44 and the oldest 68 years old; the average age was 53 years. In Elsberg's later series, which included many tumors of the lumbar and thoracic region as well, the ages ranged from 38 to 68 years, with an average of 50.

SIGNS AND SYMPTOMS

The symptoms of herniation of a vertebral disk are due to pressure of the cartilaginous mass on the cord and nerve roots. They vary with the size and position of the protruded portion.

Syndrome of Bilateral Ventral Pressure.—When the mass is so situated as to exert bilateral pressure, displacing the cord as a whole, the picture is that of any ventral neoplasm of the spinal cord. The presenting symptoms of such herniations show no constancy, in spite of the apparently close resemblance of the protruded masses in size, shape and position. So compact is the arrangement of the fiber tracts carrying the various impulses in the spinal cord that the slightest variations in the position of a discrete mass are reflected in the clinical picture. Among the initial symptoms which have been observed in this group are pain and a sensation of intense cold, with numbness, spasticity and weakness, in both lower extremities and gradual weakness and hypotonia in the muscles of the upper extremity, together with atrophy and fibrillation, though the latter may be absent.

The *sensory* disturbances are bilateral, involving pain and temperature sensation, with blunting of tactile discrimination as well as of crude tactile sensation. Vibratory sensation may also be impaired, although muscle, joint and tendon sense may or may not be affected. This dissociation of vibratory and muscle, joint and tendon sense has frequently been observed in the presence of tumors of the spinal cord and after their removal, when restoration of vibratory sensation is delayed some time after the return of all other forms of sensation. It has been suggested, in an attempt to explain this dissociation, that these impulses may be carried not only in the posterior column but in a separate pathway outside the latter. A more likely explanation would seem to be that there exists a difference in resistance to the transmission of the impulses along the fibers of the dorsal column, conduction of vibratory sensation being more easily impaired than that of muscle, joint and tendon sense. Varying degrees of pressure exerted on a nerve in a muscle-nerve preparation have been shown experimentally to interfere selectively with the conduction of impulses. A similar mechanism probably holds for fibers within the spinal cord.

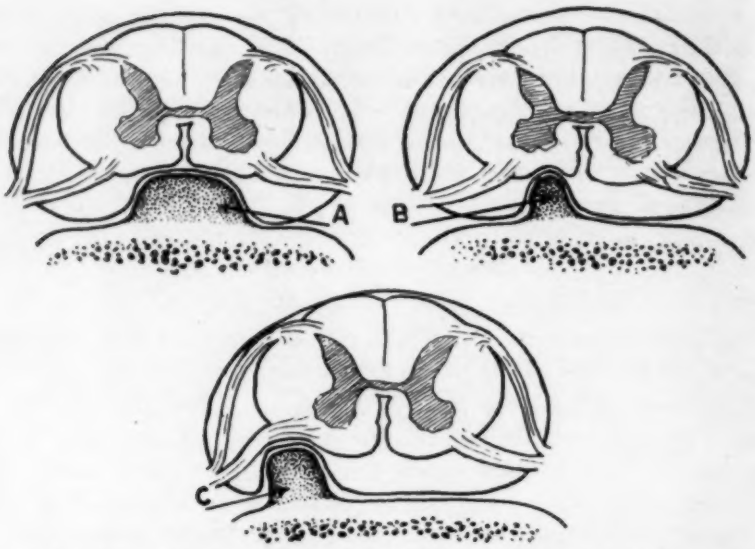

Fig. 2.—Schematic drawing to show variations in the position of the protrusion: *A* produces the syndrome of bilateral ventral pressure; *B*, the syndrome of unilateral pressure; *C*, the syndrome of root pressure. (From Stookey, 1928.)

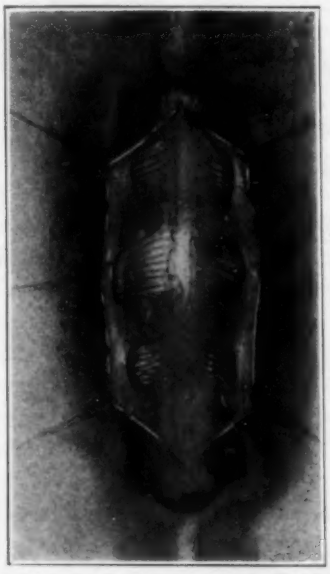

Fig. 3.—Bilateral exposure of the cervical cord showing slight dorsal angulation of the cord caused by extradural ventral herniation of the nucleus pulposus. (From Stookey, 1928.)

The signs in this group are essentially those of any ventral mass of sufficient size to exert bilateral pressure on the spinal cord with a maximum of pressure on the ventrolateral columns. They present no essential problem in diagnosis. They should readily suggest a ventrolateral tumor of the spinal cord and lead to appropriate measures.

If, however, the protrusion is narrow and situated in the midline, pressure may be exerted only on the ventral gray column and on both emerging ventral roots, without impingement on the more laterally placed spinothalamic tracts or the more dorsal pyramidal tracts. In this event

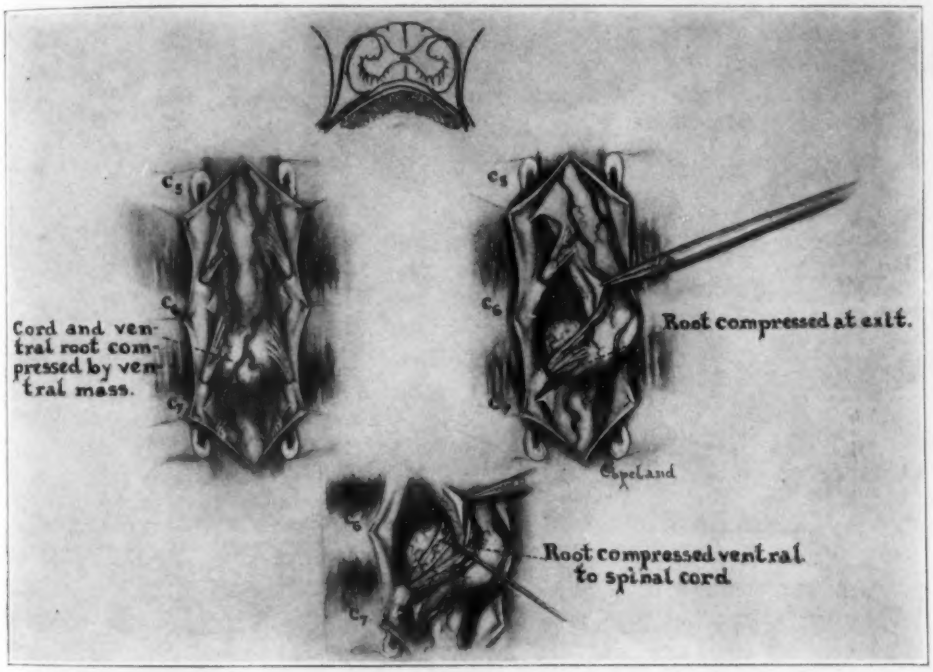
Cord and ventral root compressed by ventral mass.
Root compressed at exit.
Root compressed ventral to spinal cord.
Copeland

Fig. 4.—Small protrusion exerting bilateral pressure on both anterior horns and both ventral roots but not compressing the pyramidal or spinothalamic tracts.

the signs are referable to the ventral gray columns alone—atrophy, hypotonia and fibrillary twitchings limited to the muscles supplied by a single segment. Recently I operated on a patient with these findings, due to this type of protruded disk. No sensory changes were observed, and no signs of disturbance of the long fiber tracts were elicited. A definite ventral protrusion compressing both ventral gray columns and both ventral roots at their emergence was encountered.

Syndrome of Unilateral Ventral Pressure.—In this group of cases the herniated portion is small and is so placed that it exerts unilateral

pressure on the ventral columns of the cord, producing signs of involvement of the unilateral pyramidal tract in the lower extremity on the side of the protrusion, with local weakness and atrophy on the same side in the muscles of the cervical segments at the level of the compression. Changes in pain and temperature sense occur on the opposite side of the body at a level several segments lower than the focal motor signs.

Thus the syndrome consists of focal atrophy of the lower motor neuron type at the level of the lesion, spasticity and pyramidal tract

Fig. 5.—Roentgenogram of the cervical portion of the spinal column of the patient whose lesion is shown in figure 4. Note the narrow intervertebral disk between the bodies of the sixth and seventh cervical vertebrae (*D*) and spurs (*S*) projecting into the intervertebral foramen.

signs of the upper motor neuron type below the level of the lesion on the same side, and dissociated sensory changes on the opposite side.

The presenting symptom in these cases may be pain or stiffness of the neck, associated with pain or weakness in the region of the shoulder girdle, arm, forearm or hand, depending on the segment involved.

The *motor signs,* produced by pressure on the ventral gray matter, consist, as suggested, in rather sharply localized atrophy and fibrillations involving the muscles on the same side and indicating quite clearly the

level of cord compression. Thus, with pressure at the level of the fifth and sixth cervical segments, the deltoid, biceps, supraspinatus and supinator longus muscles are affected, whereas, pressure at the level of the eighth cervical segment will produce fibrillation and atrophy of the intrinsic muscles of the hand.

The *sensory disturbances*—loss of pain and temperature sense on the opposite side—are due to pressure on the spinothalamic tract. While

Fig. 6.—Hands of the patient whose lesion is shown in figure 4. Note the atrophy of the intrinsic muscles of the hand and main en griffe due to compression of the ventral horn and ventral roots by herniation of the nucleus pulposus.

the sensory changes are definite, they are likely to be misleading as an indication of the site of compression, since the sensory level is several segments lower than the motor level. This is to be explained by the fact that the incoming pain and temperature fibers cross obliquely in the spinal cord and do not reach the contralateral spinothalamic tract for a distance of several segments. A slight blunting of crude tactile sensation may occur, probably due also to pressure on the spinothalamic

tract. Tactile localization, muscle-joint sense and vibratory sensation, all carried in the posterior columns of the cord, are unaffected. Because of the atrophy and *dissociated* sensory changes, this syndrome is frequently attributed to intrinsic disease of the cord. Its true nature is seldom recognized unless the possibility of a ventral protrusion is considered in the differential diagnosis.

Syndrome of Nerve Root Pressure.—In a third group of cases the herniated nucleus is situated somewhat more laterally than in the other groups, compression being exerted not on the ventral column of the cord but on a nerve root near its emergence from the dura, with production of symptoms and signs referable to the root affected. Focal muscle

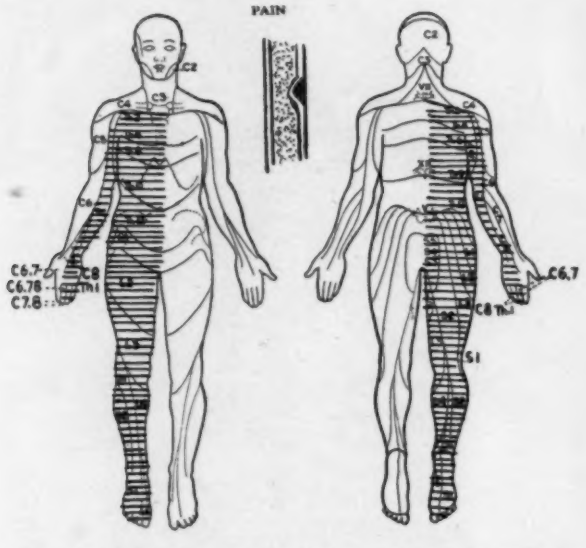

Fig. 7.—Sensory findings due to herniation of the nucleus pulposus between the fifth and sixth cervical vertebrae. The anatomic and sensory levels are not in agreement. The loss of pain and temperature sense is lower than the motor signs, which are at the level of the compression; this is due to the fact that the pain and temperature fibers cross obliquely in the spinal cord. The schematic insert was made along with the preoperative diagnosis of extradural pressure at the fifth segment.

atrophy and hypotonia limited to the distribution of the roots involved are found. The *sensory* signs are purely subjective, such as burning, gnawing and tingling sensations, which may be increased by movement of the extremity. Root pain and focal motor signs are the only diagnostic features. Lesions of this group are rare, and the clinical findings more closely resemble those associated with lumbar herniations, the picture being one of compression of a root alone and not compression of the spinal cord.

Comment.—Cervical herniations of the nucleus pulposus may thus present three different syndromes. The first of these, the syndrome of bilateral pressure, may be subdivided into two entities, depending on the size and precise position of the projection: (*a*) If the mass is small and in the midline, bilateral pressure is exerted on the ventral horns of both sides and on both ventral roots, giving rise to bilateral signs referable only to the ventral gray columns, without other evidence of compression; (*b*) if the mass is larger, the signs are indistinguishable from those of a ventral tumor of the spinal cord. The second syndrome, that of unilateral ventral pressure, due to compression of the ventral

Fig. 8.—Unilateral extradural herniation of the nucleus pulposus compressing the seventh cervical root. (From Stookey, 1928.)

horn and ventrolateral columns of one side, consists of focal atrophy and crossed dissociated sensory changes, while the third, that of unilateral root pressure, is characterized by unilateral focal atrophy and focal pain without signs of involvement of the long fiber tracts. In the presence of any one of these syndromes it seems wiser, instead of accepting a diagnosis of intrinsic disease of the cord and the hopelessness which this implies, to do an exploratory laminectomy.

Vertebral tenderness is usually without diagnostic or localizing significance in cases of cervical disk protrusion.

Accentuation of symptoms following lumbar puncture, first mentioned as evidence of a spinal tumor by Elsberg and Stookey (1922),

is of only limited application in these cases. The significance of this test lies in the fact that withdrawal of the spinal fluid buffer between the mass and the cord accentuates the pressure on the latter, thus causing an increase in the signs already present and sometimes leading to the appearance of new ones. When, however, the mass is fixed to the long wall of the vertebral canal, as in these cases, displacement of the mass on removal of the fluid does not occur.

MANOMETRIC EXAMINATION

Evidence of spinal fluid block is seldom found in cases of herniation of the nucleus pulposus, since the protruded mass is rarely of sufficient size to obstruct the subarachnoid space completely. If a complete block occurs, the signs are usually so definite and the level so obvious that a diagnosis of neoplasm is far more likely to be made than one of herniation. With the smaller masses, alterations in the dynamics of the spinal fluid are to be detected only by the most painstaking manometric studies. The jugular compression must be accurately timed with a stopwatch and the slightest alterations noted, such as a delayed rise or fall. Such alterations, carefully determined, are suggestive. Slight elevation in the total protein of the spinal fluid may be found but is not common.

INJECTIONS OF IODIZED OIL AND AIR

Because of the large amount of iodized oil found necessary to demonstrate herniation in the lumbar region, I have not felt it wise to use iodized oil in the cervical region, since the manipulations necessary to demonstrate alterations in the column may allow the fluid to enter the basal cisterns and even spread over the cerebral cortex, where it may remain, entrapped within the cranial cavity. Naffziger, Fleming and Jones found iodized poppyseed oil over the cerebral cortex in follow-up examinations of patients after the oil had been injected for the diagnosis of lumbar herniations. Such an occurrence would seem far more likely to follow the manipulations necessary to establish the diagnosis of a protrusion in the cervical region. Injection of air into the lumbar sac has been advocated by Stookey, Dyke and Scarff (1937) for the diagnosis of lumbar herniations, but this method has not been employed for cervical herniations since, as explained originally, it would require a complete, literally airtight block of the subarachnoid space to be of diagnostic value. With a compressive lesion of the cervical cord of this magnitude, the clinical evidence is so obvious that the test has not seemed necessary. In most cases the herniation is so small and discrete that it does not cause sufficient obstruction of the subarachnoid space to produce a manometric block, much less a block to passage of air.

If air is used in the diagnosis of cervical herniation, a sufficient amount must be injected to fill the cerebral ventricles and the cervical subarachnoid space. Thus, a combined encephalogram and myelogram

must be done. My associates and I have not had sufficient experience with this procedure in the rather rare cases of cervical herniation to estimate its value, though, if this condition is suspected and the signs are vague, the method is well worth trying, as we have done on occasion.

ROENTGEN EXAMINATION

In the original article on cervical lesions of this type it was stated that roentgen examination of the cervical column had given negative

Fig. 9.—Oblique roentgenogram of the cervical portion of the spine column showing calcified spurs (*S*) projecting into the intervertebral foramen, producing narrowing of the intervertebral foramen and compression of the emerging nerve root.

results in my cases. At that time the significance of a narrowed intervertebral space was not appreciated, and though a careful search was made for projections into the intervertebral foramens, oblique stereoscopic plates designed to show the intervertebral foramens were not made. Narrowing of the disk space between the fifth and sixth cervical vertebrae and between the seventh cervical and first thoracic vertebrae is often encountered, even when no signs of herniation of the disk are

present. This sign is of value, therefore, only when accompanied by definite neurologic signs suggestive of one of the syndromes of compression. Oblique stereoscopic plates have proved useful in ruling out the presence of spurs projecting within the intervertebral foramens and causing compression of the root at the foramen clinically indistinguishable from that within the vertebral canal due to laterally placed protrusion. Occasionally, calcification in the herniated nucleus may be noted, and bony spurs projecting into the vertebral canal may be seen.

OPERABILITY AND RESULTS

The end results of operations for cervical herniations are not as encouraging as those of operations for spinal neoplasms, removal of which is followed by rapid return of function and, on the whole, rather brilliant results. Possibly, if the results were compared only with those of operations for ventral extradural tumors, the disparity would be less. Removal of ventral extradural protruded masses is especially difficult, owing to their relative inaccessibility and to troublesome bleeding from the extradural venous plexuses when the dura along the ventral part of the canal is cut to expose the herniation. Masses firmly adherent to the underlying vertebrae are, moreover, more difficult to remove than soft tumors without firm attachments. In several cases, because of ossification of the protruded mass, only partial removal could be accomplished, but in others the mass could be removed completely. Recovery of function took place, however, more slowly and was not as complete as following removal of a tumor of the spinal cord. Such delay in recovery may be due in part to the fact that the lesion is hard and relatively sharply discrete and in part to the fact that the diagnosis is probably made in the majority of instances only after the lesion has been in existence a considerable time. Compression under these circumstances is likely to produce a more permanent degenerative change in the spinal cord than occurs as a result of the less circumscribed and more easily recognized soft tumor.

Another factor militating against complete recovery is incompleteness of removal. In view of the nature of the protrusion and of its source it seems possible that additional material may protrude when movements of the neck are again resumed. While it is not known that this takes place, it is conceivable that it does. Chamberlain and Young (1939) reported the observation by Dr. Temple Fay of alterations in the amount of protrusion in the lumbar region on flexion and extension of the spine during operation.

Type of Laminectomy.—Having tried both bilateral laminectomy and hemilaminectomy in the approach to the ventral surface of the spinal

cord in the cervical region, I feel that hemilaminectomy as introduced by Alfred S. Taylor (1910) is the operation of choice, especially when the mass lies somewhat to one side of the cord, as it most frequently does in this region. In hemilaminectomy the arches are removed farther ventrally and laterally than in bilateral hemilaminectomy, and a more

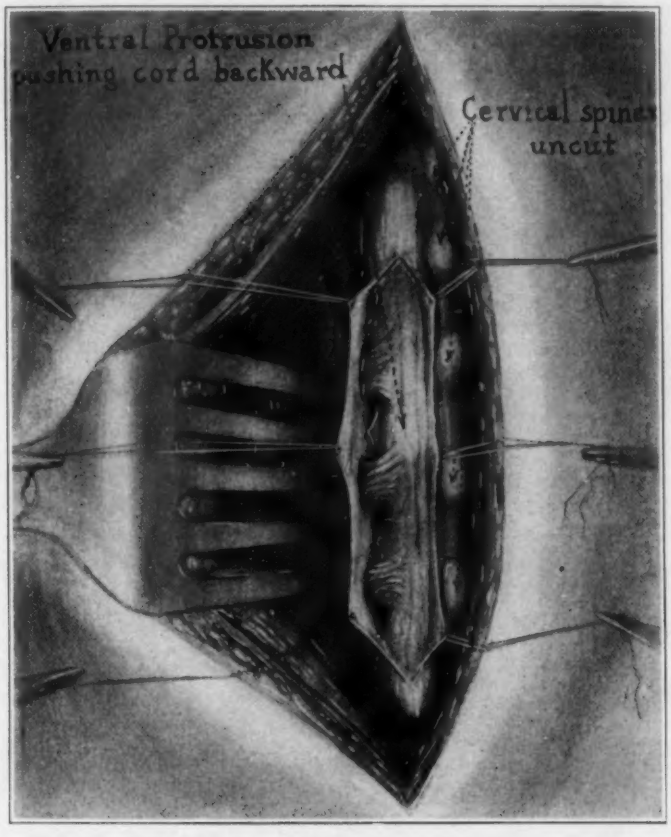

Fig. 10.—Hemilaminectmoy with exposure of the cervical cord, according to the technic of Alfred S. Taylor. This is the operation of choice for extradural ventral herniation of the nucleus pulposus. The arches on the left side of the vertebrae have been removed as far as the articular processes. The vertebral spines, the intraspinous ligaments and the vertebral arches on the right side have not been disturbed. The dura on the right has been opened and retracted. A slight dorsal angulation of the cord due to ventral herniation of the nucleus pulposus is noted. (From Stookey, 1928.)

direct approach to the ventral surface is thus afforded. As bleeding is encountered when an extradural approach is made, this route is usually avoided in the cervical region. Furthermore, when the cord

is rotated, its visualization is advisable in order to avoid injuring it, as retraction of the cord with the dura unopened may lead to a greater trauma than occurs when the cord is exposed. When the protrusion is markedly lateral, however, sufficient retraction can be accomplished without opening the dura to permit removal of the herniated portion without trauma to the cord. Taylor's hemilaminectomy offers the further advantage that it disturbs the relationships of the vertebral column less than bilateral laminectomy. This is of special importance,

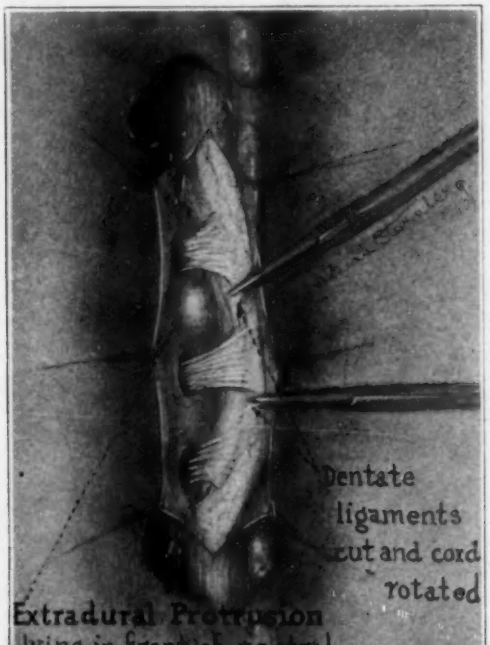

Fig. 11.—Same as figure 10. Two dentate ligaments have been cut, and the cord has been rotated, the ventral surface of the dura being brought into view. A ventral extradural herniation is seen beneath the dura. A longitudinal incision in the dura should be made over the herniation. (From Stookey, 1928.)

since the stability of the vertebral column may already be altered by the changes in the relations of the vertebral bodies and the intervening intervertebral disks found in herniations.

When the dura is opened and the cord brought into view, one or two dentate ligaments are grasped with mosquito forceps and cut to allow rotation of the cord and retraction to permit adequate exposure of the ventral aspect of the dura. A paramedian incision of 1 to 2 cm.

is made in the ventral dura over the protruding portion of the nucleus pulposus. The protruding part can then be removed in pieces, usually in the form of thin layers of frayed cartilaginous tissue. After this removal, a depression having a relatively smooth base can be seen on the ventral surface of the vertebral bodies. The ventral opening in the dura is then sutured with one or two fine silk sutures.

If the protruded portion is large and extends across the midline, the opposite arches of one or two vertebrae immediately overlying the herniation may be removed, the hemilaminectomy being converted into a *local* bilateral laminectomy. Another paramedian incision is made in the dura on the opposite side, after rotation of the cord, and the herniated part of the disk is removed in the same manner. An approach from the opposite side will seldom be necessary.

SUMMARY

The so-called ventral extradural cervical chondroma, first recognized as a clinical entity in 1928, is now believed to be not a neoplasm but rather a portion of the nucleus pulposus protruding through the annulus fibrosus into the vertebral canal.

Such protruding parts exert pressure on the cord or nerve roots or both and give rise to three distinct syndromes: the syndrome of bilateral ventral pressure; the syndrome of unilateral ventral pressure; the syndrome of nerve root pressure.

Diagnosis of this lesion is frequently difficult, as the signs and symptoms may closely resemble those of intrinsic disease of the cord. This should be ruled out in selected cases by exploration rather than accept the hopeless outlook which such a diagnosis implies.

In the author's experience no approach gives as adequate an exposure as Taylor's hemilaminectomy for removal of herniated portions of the nucleus pulposus in the cervical region.

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CLINICAL ASPECTS OF PROTRUDED INTERVERTEBRAL DISK

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Posterior protrusion of the intervertebral disk, an entity brought to attention by Mixter and Barr,[1] who recognized the value of employing radiopaque oil as a diagnostic means, has taken its place with other pathologic conditions producing backache and sciatic pain.

I do not wish to imply that all posterior protrusions produce symptoms; however, a protrusion of sufficient size, advantageously placed, may produce pathologic changes in the nerve roots or the cauda equina sufficient to convince the most skeptical of its clinical significance.

The present study was undertaken in an attempt to present the clinical findings in a series of cases in which definite neural changes were noted at the time of exploration and removal of a posteriorly protruded intervertebral disk.

This group is composed of cases in which operation was performed at the Mayo Clinic in 1936 and 1937. All questionable cases and all cases in which no definite pathologic changes were demonstrated in the nerve roots or in the cauda equina at the time of operation have been excluded. Operation was carried out by the neurosurgical staff.

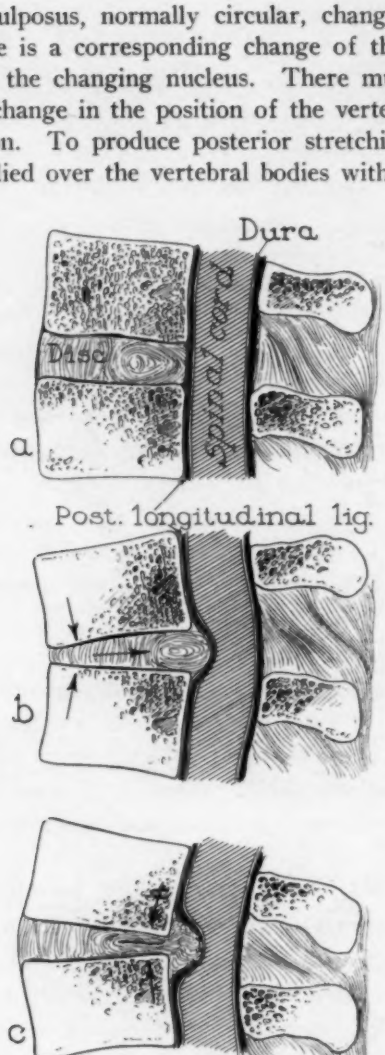
ANATOMY AND MECHANISM OF PRODUCTION

The intervertebral disk, or fibrocartilage, is composed of the annulus fibrosus and the nucleus pulposus. The annulus fibrosus is composed of laminas of fibrous tissue and fibrocartilage and is so placed at the anterior and posterior intervertebral spaces as to confine the nucleus pulposus between the vertebral bodies. The nucleus pulposus, a soft, elastic mass of fibrous tissue, is confined superiorly and inferiorly by the cartilaginous plate covering the inferior and superior portions of the vertebral bodies and anteriorly and posteriorly by the annulus fibrosus. It is confined under pressure and acts in the capacity of a shock absorber, or cushion, for the vertebral bodies.

From the Section on Orthopedic Surgery, the Mayo Clinic.

1. Mixter, W. J., and Barr, J. S.: Rupture of the Intervertebral Disc with Involvement of the Spinal Canal, New England J. Med. **211**:210-215 (Aug. 2) 1934.

The nucleus pulposus, normally circular, changes in shape under pressure, and there is a corresponding change of the annulus fibrosus to compensate for the changing nucleus. There must of necessity be an accompanying change in the position of the vertebral bodies and an uneven compression. To produce posterior stretching of the annulus, force must be applied over the vertebral bodies with the spinal column



Diagrams showing (*a*) a normal intervertebral disk; (*b*) rupture of the fibers of the annulus fibrosus and extrusion of the nucleus, and (*c*) possible changes in the annulus fibrosus and nuclear content with hyperextension.

in the position of flexion. The anterior aspect of the intervertebral space is narrowed, with corresponding widening of the interspace from the front to the back. There results a tensing of the posterior portion of the annulus with a posterior bulging from the shifting nucleus. If sufficient force is applied, there may result one of two changes: (1) an acute rupture of the posterior portion of the annulus, probably

occurring at one or the other of its vertebral attachments, with a release of its nuclear content and loss of compression, or (2) a gradual change in the posterior portion of the annulus by disruption of its fibers with a gradual loss of resilience and, finally, force sufficient to complete the rupture with escape of the nuclear content of the annulus. In the course of the gradual rupture there may be recurrent bulge producing recurrent symptoms (see accompanying illustration, *a* and *b*).

There is another structure to be considered in conjunction with a posterior protrusion. This is the posterior longitudinal ligament, which in the earlier phases of rupture of the annulus may prevent production of clinical symptoms other than transient backache. The posterior longitudinal ligament is thickened over the vertebral bodies, thins out as it extends laterally and becomes adherent to the fibrocartilage. By its elastic qualities it may temporarily restrain the ruptured annulus and nucleus and later become stretched, thus permitting the characteristic bulge of a posterior protrusion in a lateral aspect. The anatomic structure of the posterior longitudinal ligament probably accounts for the unilateral nature of this syndrome, which may occur on either side and at more than one level; however, protrusions in the midline can occur. More correctly speaking, they are probably bilateral protrusions.

PATHOLOGIC PICTURE

The pathologic picture of a posteriorly protruded disk is that of nerve compression (by nerve compression I mean that the protrusion has compressed a root laterally and posteriorly against the pedicle of the vertebra and on the ligamentum flavum) from a ruptured annulus fibrosus, an extruded nucleus or a combination of the two. From the pathologic examinations in 100 cases forming the basis of this study, the predominant finding was degenerating fibrocartilage. In this series of cases only 15 per cent of the specimens showed remnants of notochordal tissue, and in a few instances degenerating hyaline cartilage was noted. Thirty-seven per cent of all specimens showed evidence of edema. This fact has been offered by Deucher and Love [2] as a possible explanation for the recurrent attacks of sciatic pain with repeated injuries.

The pathologic appearance at operation is that of a firm, hard protrusion at the posterolateral intervertebral space. On exposure by incision of the posterior longitudinal ligament, this protrusion may be seen to extrude itself into the wound, or it may be found firmly adherent, necessitating excision for its removal. Not infrequently,

2. Deucher, W. G., and Love, J. G.: Pathologic Aspects of Posterior Protrusions of the Intervertebral Disks, Arch. Path. **27**:201-211 (Feb.) 1939.

degenerating, cheeselike material is seen to extrude on incision of the lateral attachment of the posterior longitudinal ligament. There may also occur, though rarely, extrusion into the canal of several fragments, which are fibrous particles of the nucleus pulposus. It would appear from the anatomic and pathologic pictures that the presenting tumefaction in this syndrome is due to protrusion of the nucleus covered by the annulus fibrosus which has undergone fibrous changes. There may be an occasional case in which fibrous fragments of the dislodged nucleus become so placed as to produce nerve compression.

CLINICAL HISTORY

The clinical history resulting from a posterior protrusion with accompanying neural irritation commonly follows one of two patterns. 1. There may be recurrent "low backache," with the initial onset attributed to an injury severe enough to be remembered. There also may be an association of repeated injuries with an acute onset of sciatic pain following an apparently trivial injury, such as slipping, tripping or falling in a sitting position, in which there occur sudden flexion and torsion of the spinal column. The sciatic pain may be continuous or recurrent. There may be an associated paresthesia, which is commonly complained of in the form of numbness, tingling or needle-like pains over the buttock, the posterior aspect of the thigh, the posterolateral aspect of the leg or the dorsum of the foot. 2. There may be backache and sciatica together, continuous and with or without a history of remembered injury. The injury is frequently trivial and seemingly insufficient to cause an acute rupture of the annulus fibrosus. In this type, paresthesia is also a common complaint. In the presence of persistent sacral pain without disturbance of the achilles tendon reflex, posteriorly protruded disk at a high level should be suspected.

The sciatic pain is aggravated by activity, coughing, sneezing and motions which induce traction on the nerve roots. On close questioning regarding relief with rest, it is found that most of the patients become free from pain by lying absolutely immobile and that any motion reproduces the pain. Many positions may be assumed, the most common of which is lying on the side with the spinal column and the thighs flexed. From this clinical picture there may be many variations, such as relief on walking or standing and pain only in the buttock, thigh or leg. There are varied levels of pain and anesthesia. The effect of traction on the extremities varies: in some cases the sciatic pain is intensified and traction is intolerable, while in others it gives temporary relief, the pain recurring when activity is allowed. There are other cases in which traction affords periods of complete relief.

CLINICAL DATA

Group A.—Of 100 cases studied, there was a history in 23 of injury severe enough to initiate symptoms unquestionably attributable to the injury.

Group A-1.—In 9 cases of this group, backache and sciatica occurred together; in 7 these symptoms were continuous, and in 2 they were recurrent.

Group A-2.—In 2 of the 23 cases there was continuous sciatic pain alone.

Group A-3.—In 12 of the group of 23 cases there was a history of many years of backache with late onset of pain over the distribution of the sciatic nerve. In 7 of these 12 there had been recurrent attacks of sciatic pain without a history of secondary injury to produce the onset of the sciatic pain, and in 5 cases there had been recent and persistent sciatic pain associated with a secondary minor injury.

It was of interest to note that in 17 of the 23 cases the injury was sustained with the spinal column in a position of flexion and torsion; in the other 6 the posture was not known.

Group B.—In 9 cases of the group studied, there was a history of many years of backache without known injury to produce the symptoms. In all of these cases the onset of sciatic pain occurred while the patient was doing some type of work which required standing with the spinal column in a position of flexion, such as shoveling snow or pitching hay, after which the pain was persistent.

Group C.—In 68 cases of the series, the patients did not remember any injury of sufficient magnitude to produce onset of the symptoms.

Group C-1.—In 12 of this group of 13 cases, the onset of backache and that of sciatic pain were simultaneous, and both symptoms were persistent; in 1 case there was continuous backache with recurrent sciatic pain. In 11 cases the symptoms had been present a comparatively short time (several months), and in the remaining 2 cases the duration was several years.

Group C-2.—In 13 of the 68 cases there had been recurrent backache and recurrent sciatic pain for many years, and in 9 of these there had been several months of continuous sciatic pain prior to the patient's admission to the clinic.

Group C-3.—In 34 cases there was a history of many months to many years of backache and, later, onset of sciatic pain which had persisted continuously. The average duration of backache was seven and nine-tenths years, and the range was from one to thirty years. The average duration of persistent sciatic pain was from three to six months.

Group C-4.—In 8 cases of the group of 68 there was a history of sciatic pain alone. In 2 of these 8 there had been continuous pain of three and four months' duration respectively, and in 6 there had been recurrent sciatic pain with an average duration of three years.

Comment.—From the foregoing data it is readily seen how difficult it is to draw any definite conclusion other than that the syndrome may include the following manifestations: (1) recurrent backache and recurrent sciatic pain, (2) continuous backache and recurrent sciatic pain, (3) continuous backache and continuous sciatic pain, (4) continuous sciatic pain without backache or (5) recurrent sciatic pain without backache.

From the pathologic anatomy one must conclude that the protrusion results from an injury or injuries or possibly from disease, although so far as I know the latter has not been reported. The impression one gets in reviewing the cases is that injury is the basis of all posterior protrusions but that the degree of the injury or multiple injuries determines the clinical history and the clinical course of the syndrome.

With a severe injury there may be an acute rupture of the posterior portion of the annulus and a corresponding bulge of sufficient degree and so placed that continuous symptoms are produced. There may be a spontaneous rupture from an apparently trivial injury in a previously damaged annulus. Also, there is some mechanism whereby the pressure from this posterior protrusion on the nerve root is released, producing remissions between the attacks. The nature of this mechanism constitutes a problem for much speculation. Is there recurrent edema of the protrusion which produces intermittent pain? Is the posterior longitudinal ligament an agent in gradually lessening the protrusion following rupture of the annulus fibrosus, and does it further assist in reducing recurrent displacements of the annulus fibrosus? Does the nucleus pulposus produce recurrent sciatic pain by shifting in and out of its anatomic position between the vertebral bodies, or does the partially or wholly extruded nucleus displace the annulus fibrosus in such a manner that there is resulting compression of the nerve roots from the annulus? Is the intermittency of the symptoms dependent on reduction of the nucleus into its intervertebral space, thereby allowing anatomic reposition of the annulus?

Deucher and Love [2] have suggested that recurrent edema is probably the explanation for recurrent sciatic pain associated with posterior protrusion of the intervertebral disk.

In 82 of 100 cases relief was noted with rest, in some obtained simply by inactivity and in others produced by a particular attitude assumed on lying down, such as flexion of the affected thigh on the abdomen or lying on one side or the other. In 64 cases the patient complained of some type of paresthesia.

CLINICAL FINDINGS

In attempting to describe the clinical findings from which a diagnosis can be made, a certain group of cases must be considered in which the findings are characteristic of posterior protrusion. From this picture there may be many variations, even in those cases in which little clinical evidence is presented at the time of examination and a diagnosis is made from the history and the positive findings as shown by radiopaque oil or air studies. Not infrequently in this group is seen the patient with a large posterior protrusion in a symptomatically quiescent state, and, as has been stated before, this presents one of the interesting questions raised of the syndrome, namely, why there is an interval of quiescence of symptoms.

Positive Findings.—In 50 of the group of 100 cases, there was unilaterally limited "straight leg raising;" in 24 there was a bilaterally limited "straight leg raising," and in 26 the patients were considered normal in this respect. In 17 cases there was atrophy of either the buttock or the extremity or both, 13 of these cases occurring in groups A and C-3.

Inspection.—The characteristic position of the spinal column in the cases of acute involvement was a list to the unaffected side, with scoliosis of the lumbar vertebrae. This was noted in 33 of 100 cases. In only 5 cases was there a list to the affected side. In 24 cases the posture was good; in 21 cases no mention of posture was made, and one assumes that it was good. In 1 case there was alternating scoliosis, which is almost pathognomonic of a bilateral or midline posterior protrusion; however, there is commonly a bilateral protrusion without alternating scoliosis. In 16 cases there was obliteration of the lumbar lordosis with generalized flattening of the back.

Palpation.—In 50 cases tenderness was elicited over the lumbosacral joint and was felt to arise from pathologic changes in this joint. Possibly in some cases the tenderness resulted from a lesion of the fourth and fifth lumbar interspace. In 50 cases tenderness could not be elicited on physical examination or was of such little significance that it was not noted. In 39 there was tenderness over the region of the sacroiliac joint on the affected side, which is probably of little clinical significance. In 80 cases, or 80 per cent, there was definite limitation of motion, particularly in flexion of the spinal column.

ROENTGEN EXAMINATION

Of 98 cases in which fluoroscopic examination with radiopaque oil was done, there were 93 in which a positive defect was found, 4 in which the procedure was a failure and 1 in which a protruded disk was found at the interspace between the fourth and fifth lumbar vertebrae

at operation after the results of roentgen examination had been reported as negative. In the 2 remaining cases of the series direct exploration was carried out without roentgen examination. Camp [3] reported that by the use of radiopaque oil accurate diagnoses have been made in 92.3 per cent of 210 cases observed at the Mayo Clinic. In view of the fact that radiopaque oil may give rise to radiculitis, air studies have been employed when advisable, and resort has been made to radiopaque oil when air studies failed to demonstrate a suspected lesion. Roentgen examination after injection of air into the spinal canal has been referred to by others as myelography. In the Mayo Clinic it is referred to as taking a spinogram and is employed as a means of diagnosing a protruded intervertebral disk.

Skeletal Changes.—In 34 patients changes were noted on roentgen examination of the bony structures in association with the posterior protrusion; there were 1 with spondylolisthesis, 2 with "facet changes," 3 with hypertrophic changes and 28 with narrowing of the lumbosacral or the fourth and fifth lumbar interspace, all corresponding to the site at which the posterior protrusion occurred. Of this group of 28 patients, 13 were in group C-3, the group with many months to years of backache.

Location.—Forty-one of the posterior protrusions occurred at the fourth and fifth lumbar interspace, 46 at the lumbosacral joint, 8 at the third and fourth lumbar interspace and 1 at the second and third lumbar interspace. Four patients showed multiple protrusions. Of this group there were 28 midline or bilateral protrusions of the disks. Each of the remaining 72 protrusions was unilateral.

Neurologic Examination.—The most important finding in neurologic examination was the reporting of a diminished achilles tendon reflex; however, a normal reflex does not preclude the finding of a posteriorly protruded disk. In 66 of the group of 100 cases there was evidence of a diminished achilles tendon reflex. In 13 cases this was graded —1 on a basis of —1 to —4; in 8 cases it was graded —2; in 14 cases it was graded —3, and in 31 cases it was graded —4.

Of the group of 100 cases there were 12 in which there was bilateral sciatic pain and in which a bilateral protrusion was found. The findings in this series compare closely with those reported by Love [4] and by Love and Walsh [5] on different occasions, minor discrepancies resulting from the choosing of a small series of cases.

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3. Camp, J. D.: Personal communication to the author.

4. Love, J. G.: Intractable Low Back and Sciatic Pain Due to Protruded Intervertebral Disks: Diagnosis and Treatment, Minnesota Med. **21**:832-838 (Dec.) 1938.

5. Love, J. G., and Walsh, M. N.: Protruded Intervertebral Disks: Report of One Hundred Cases in Which Operation Was Performed, J. A. M. A. **111**: 396-400 (July 30) 1938.

TOTAL PROTEIN

The presence of high values for total protein in the spinal fluid has been of considerable importance in the neurologic examinations for intraspinal lesions, and one would anticipate an elevation of the value for this substance in the presence of a posterior protrusion of the intervertebral disk. This, however, was not always the case; the protein content of the spinal fluid has been found to be normal or at a low level in some cases in which a large posterior protrusion was present. The significance of the elevated value for protein in this syndrome is that it adds more positive evidence to that on the basis of which a lesion is already suspected. In cases in which clinical examination is not diagnostic and the results of neurologic examination are objectively negative, it may be a reason for proceeding with a more exhaustive study, including a roentgen examination of the spinal canal after injection of air or radiopaque oil. This may be particularly advisable for the orthopedist or the neurologist, who does not have ready access to fluoroscopic or roentgen facilities. In 4 cases of this group, estimation was not made, and in the other 96 cases the average protein content of the spinal fluid was 53.8 mg. per hundred cubic centimeters. In 36 cases the protein content did not exceed 40 mg. per hundred cubic centimeters. In 4 cases it was 45 mg. In the remaining 56 cases the protein content per hundred cubic centimeters of spinal fluid was more than 45 mg. and was considered to be of definite pathologic significance. The highest protein content for any individual patient was 220 mg. per hundred cubic centimeters of spinal fluid.

Average of Patients by Groups.—Group A was found to have an average value for total protein of 45.5 mg. per hundred cubic centimeters of spinal fluid. In 9 cases of group A, the value for total protein was normal; in 2 the value was 45 mg. per hundred cubic centimeters of spinal fluid; in 3 no estimation was done. In the remaining 9 cases there was a definite increase above normal in the value for protein.

In group B there was an average value for total protein of 50 mg. per hundred cubic centimeters of spinal fluid. In 4 cases the values for protein were normal. In the remaining 5 there was a definite elevation above the normal level.

In group C-1, the average value for protein was 58.5 mg. per hundred cubic centimeters of spinal fluid. In 4 cases there were normal values, and in 9 there was an elevation above the normal level.

In group C-2, the average value for protein was 64.6 mg. per hundred cubic centimeters of spinal fluid. In 3 cases there were normal values; in 1 the total protein was not estimated, and in 1 there was a value of 45 mg. In the remaining 8 cases there was an elevation above the normal level.

In group C-3, the average value for total protein was 54.4 mg. per hundred cubic centimeters of spinal fluid. There were normal values in 14 cases; in 2 there was a value of 45 mg., and in 18 there was an elevation above the normal level.

In group C-4 there were 8 cases in which sciatica was continuous. In 4 of these the value for total protein was normal, and in 4 it was elevated. The average value was 50 mg.

SUMMARY

This is an attempt to present the findings as noted on orthopedic examination and to a lesser extent on neurologic examination in 100 cases in which posterior protrusion of an intervertebral disk was of apparent significance in producing symptoms. It is felt that this syndrome presents sufficient clinical evidence in the history and the examination to arouse suspicion of a posteriorly protruded disk in practically all cases and that in the majority the condition can be diagnosed on the clinical history and examination alone. However, roentgen examination should probably be carried out on all patients to determine the location of the protrusion or protrusions. Also, there is a group of patients in the quiescent period, for whom a roentgen examination is necessary for demonstration of a suspected lesion. There is still a third group, with the usual clinical findings and history, in whose cases the results of the roentgen examination are negative but must be considered in deciding whether to make an exploratory examination.

It is my impression after completing this study that a possible explanation of the intermittency of symptoms is that in some manner a change in position of the dislodged nucleus beneath the annulus fibrosus results in reduction to approximately normal anatomic position. From the cases observed at operation, one would anticipate that this could occur by reduction of a protruded nucleus pulposus between the intervertebral bodies, permitting a collapse of the annulus and a release of nerve compression.

I should also like to mention a test which is felt to be of significance in examination of patients with posterior protrusion, that of a sudden unexpected hyperextension at the lower lumbar vertebrae. When the result is positive, pain is reproduced over the course of the affected sciatic nerve. The mechanism whereby this occurs is probably a narrowing of the posterior interspace with a sudden relative increase in the posterior bulge, with sudden pressure on the nerve root (see illustration, *C*).

As regards the treatment of this lesion, it is confined to the neurosurgical division of the clinic and consists of laminectomy and removal

of the ligamentum flavum and the disk, in which procedure the articular facets are preserved. There are many cases in which the consideration and aid of the orthopedist are required in association with the neurosurgical procedure, and it is essential to have close harmony between the orthopedist and the neurosurgeon in the handling of these cases. The cases in which a combined procedure is employed, that of hemilaminectomy and removal of the disk and bone grafting, include such conditions as spondylolisthesis, separated neural arch without slipping of the vertebral body and marked narrowing of the intervertebral space with hypertrophic arthritic changes.

Dr. J. W. Kernohan reviewed the pathologic specimens. Members of the neurosurgical staff gave valuable suggestions and permitted access to the surgical notes.

IODIZED OIL MYELOGRAPHY

USE IN THE DIAGNOSIS OF RUPTURE OF THE INTERVERTEBRAL DISK INTO THE SPINAL CANAL

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Roentgen examination after the injection of iodized oil into the spinal subarachnoid spaces (iodized oil myelography) is the most important step in the diagnosis of rupture of the intervertebral disk into the spinal canal. The accurate roentgen localization of the lesion is of distinct value to the surgeon, and the demonstration of the mechanism by which the fragment of the ruptured disk presses on the cauda equina has added weight to the evidence that rupture of an intervertebral disk into the spinal canal is a definite clinical entity.

A positive diagnosis of posterior protrusion of an intervertebral disk into the spinal canal has been made at the Massachusetts General Hospital in 133 cases by the use of iodized oil, roentgenoscopy and instantaneous films taken during roentgenoscopic examination.[1] All except 9 of these diagnoses were proved correct at operation. There were 2 cases of negative results on roentgen examination with positive operative findings and 2 of questionable roentgen diagnoses with positive operative findings. A dilated arachnoid vein, a fractured pedicle, a small osteoma and in 2 cases a thickened ligamentum flavum were misinterpreted as ruptured intervertebral disks. Surgical exploration has been done with negative results in 9 cases, of which negative results were expected from roentgen examination in 7 and positive in 2. The accuracy of diagnosis is therefore 93 per cent.

Air myelography is rapidly coming into use in the diagnosis of rupture of the intervertebral disk.[2] The accuracy of this type of

1. Mixter, W. J.: Protrusion of the Lumbar Intervertebral Disks, read at the Fourth International Neurological Congress, Copenhagen, Denmark, Aug. 24, 1939; other unpublished data.

2. Young, B. R., and Scott, M.: Air Myelography: The Substitution of Air for Lipoidal in Roentgen Visualization of Tumors and Other Structures in the Spinal Canal, Am. J. Roentgenol. **39**:187-192, 1938. Dandy, W. E.: Ventriculography Following Injection of Air into Cerebral Ventricles, Ann. Surg. **68**:5-11, 1918. Coggeshall, H. C., and von Storch, T. J. C.: Diagnostic Value of Myelographic Studies of Caudal Dural Sac, Arch. Neurol. & Psychiat. **31**:611-613 (March) 1934. Van Wagenen, W. P.: Roentgenological Localization of Spinal Subarachnoid Block by Use of Air in Subarachnoid Space, Ann. Surg. **99**:939-943,

(Footnote continued on next page)

examination varies considerably in the hands of different workers. Improvements will undoubtedly be made in the technic of this examination and the accuracy of roentgen interpretation, but at present it is doubtful that a positive diagnosis of rupture of the intervertebral disk can be made in over 50 per cent of the cases. Even if an error of 50 per cent in the diagnosis of rupture of the disk by air myelography persists, the procedure should nevertheless be used, as a preliminary, before the injection of iodized oil, because in that way it will probably be possible to eliminate the use of iodized oil and its questionable ill effects in one half of the patients. Air myelography is of distinct value when the findings are unequivocally positive, but it is of little value when the findings are equivocal or negative.

The indications and contraindications for iodized oil myelography have been discussed at length in the literature.[3] It has been maintained that iodized oil may be safely injected into the spinal subarachnoid spaces if the procedure is properly carried out, but the indiscriminate use of this valuable method of diagnosis is to be avoided. The patient who is to be subjected to this examination should be carefully selected. There should be no doubt that he is suffering from a disease sufficiently disabling to warrant a major surgical procedure for relief. The discovery of a narrowed joint space by plain roentgenograms is not an indication for the examination with iodized oil. Even though this finding may indicate rupture of the disk there is no indication that it is pressing upon the cauda equina.

It cannot be too strongly emphasized that iodized oil in the spinal canal is a foreign body and remains as such for many years. Of over 200 patients subjected to this type of examination at the Massachusetts General Hospital, 4 have had fairly persistent untoward symptoms presumably developing from the use of iodized oil. Two complained of headaches coincident with the lodgment of the iodized oil in the cranial

1934. Camp, J. D.: The Comparative Value of Subarchnoid Air Versus Lipiodol in the Diagnosis of Intraspinal Protrusion of the Intervertebral Disks and of Hypertrophy of the Ligamentum Flavum, read at the Fortieth Annual Meeting of the American Roentgen Ray Society, Chicago, Sept. 21, 1939.

3. Mixter, W. J., and Ayer, J. B.: Herniation or Rupture of the Intervertebral Disk into the Spinal Canal, New England J. Med. **213**:385-393, 1935. Harkins, H. N.: Use of Iodized Poppy Seed Oil in Differential Diagnosis Between Tumors of Conus Medullaris and of Cauda Equina, Arch. Neurol. & Psychiat. **31**:483-503 (March) 1934. Globus, J. H., and Strauss, I.: Intraspinal Iodolography: Subarachnoid Injection of Oil as Aid in Detection and Localization of Lesions Compressing Spinal Cord, ibid. **21**:1331-1396 (June) 1929. Mixter, W. J., and Barr, J. S.: Rupture of the Intervertebral Disk with Involvement of Spinal Canal, New England J. Med. **211**:210-215, 1934. Barr, J. S.; Hampton, A. O., and Mixter, W. J.: Pain Low in the Back and Sciatica Due to Lesions of Intervertebral Disks, J. A. M. A. **109**:1265-1270 (Oct. 16) 1937. Lindblom, A. F.: On the Effects of Various Iodized Oils on the Meninges, Acta med. Scandinav. **76**:395-402, 1939.

vault. One complained of pain referable to a dorsal root and another of coccygodynia. In 1 of the patients suffering with headaches the oil was caused to enter the cranial cavity by placing the patient in the Trendelenburg position for treatment of shock. This patient had had three times the usual quantity of oil injected, and it had been incompletely removed. In the other patient headache followed the roentgenoscopic examination, at the time of which the oil was caused to enter the cranium. There are other patients in the group who have oil in their cranial vaults without any symptoms, but, since the oil cannot be dislodged from the cranial subarachnoid spaces or ventricles, great care should be taken to prevent it from entering those areas. The patient should be instructed not to stand on his head until the oil has been removed.

If the patient has had a previous subarachnoid injection of air it is advisable to withhold injection of oil until the air has completely disappeared and normal spinal fluid pressure has returned, because collapse of the subarachnoid space or retention of air prevents the free flow of iodized oil during roentgenoscopic examination, and this may cause multiple false filling defects. A previous lumbar puncture for studies of the spinal fluid may result in a leak of spinal fluid which interferes with the examination. The difficulties and dangers of injecting the oil when a free flow of spinal fluid is not obtained are obvious. Several instances of subdural and extradural injections of iodized oil have occurred under these circumstances and also even when a free flow of fluid was present. The oil should be heated before injection to reduce its viscosity, which makes it difficult to maintain the point of the needle in the subarachnoid spaces while the pressure required to empty the syringe is applied. Care should be taken to select fresh iodized oil. This can be determined by the date marked on the ampule and also by the color of the oil. Fresh iodized poppyseed oil is practically colorless, but when deterioration occurs it becomes amber or yellow. It is difficult to determine slight changes in color unless a fresh ampule is available for colorimetric comparison. There is a definite variation in the reaction of the patient to the injection of iodized oil into the subarachnoid spaces. It would appear that there must be some difference in the oil itself. Some patients have no symptoms, while others have fairly severe transient reactions, but, as has been stated, these reactions are seldom persistent. The reports in the literature of persistent untoward reaction have originated from sources where iodized oil is used infrequently, and this suggests that old or deteriorated oil may have been used. It is necessary to inject 4 to 5 cc. (one ampule) of iodized oil into the subarachnoid spaces in order to allow a satisfactory roentgen examination. Smaller quantities have been tried, and errors were common unless the

spinal fluid was blocked. The roentgen examination can be done at any time after the injection of iodized oil, because it remains freely movable even after several years. Most of the roentgen examinations are made on the same day as iodized oil is injected. The only contraindication for the immediate examination is the infrequent occurrences of a "lumbar puncture headache." On the day after the injection, the patient may be more uncomfortable, and it may be necessary to give appropriate drugs for the relief of pain so that the patient may be more able to cooperate in the examination.

ROENTGEN TECHNIC FOR IODIZED OIL MYELOGRAPHY

Since over 90 per cent of ruptures of the intervertebral disks which produce pressure on the spinal cord or cauda equina occur in the lumbar area, only the technic of examination of this area will be discussed. For the complete examination of the lumbar subarachnoid spaces with iodized oil it is necessary to use a tilting motor-driven roentgenoscopic table. It is possible, however, to obtain a fairly satisfactory examination of the areas of the fourth and the fifth lumbar intervertebral disk by using a horizontal roentgenoscopic table. A quick change-over switch which allows instantaneous exposure of films during the roentgenoscopic examination is necessary in either case. The purpose of the examination is to demonstrate a small, anteriorly placed, unilateral, extradural pressure defect in the subarachnoid spaces. Since 5 cc. of iodized oil fills only a small portion of the subarachnoid spaces, it is necessary to cause this oil to pass up and down the spinal canal over the areas of the disks. The oil used is of the "heavy" type and consequently gravitates posteriorly when the patient is supine and anteriorly when the patient is prone. Because of the small amount of oil and the effect of gravity, it is necessary to examine the patient in all positions in order to rule out a small extradural defect, but when searching for a ruptured intervertebral disk it is usually necessary to examine the patient only face down, or prone, as the oil crosses the area of each disk. An effort should be made to have the maximum amount of oil occupy the level of each disk; i. e., maximum filling opposite each intervertebral disk must be obtained before it is possible to rule out disease. The examination is begun with the patient facing the fluoroscopic table in the upright position. In this position all the iodized oil is in one mass and occupies the sacral cul-de-sac. In some patients the upper level of the oil may reach the middle of the fourth lumbar vertebra, but in the average patient the oil barely reaches the level of the fifth disk. The anteroposterior view, both the oblique views and the lateral view of the column of iodized oil are taken with the patient upright if the oil extends above the level of the fifth disk. It is necessary to take films as the oil occupies the

level of each disk, because some of the filling defects are too small to be visualized with the fluoroscope. This is particularly true with unilateral rupture of the fifth lumbar disk. The patient is then slowly brought to the horizontal face-down position, and just before it is reached the iodized oil usually occupies the area of the fourth disk. Roentgenoscopic observations are made, and four views of the spine are repeated. The patient is then further manipulated, to the Trendelenburg position, and as the oil crosses the area of each disk, observations are made and films are taken. If examination of the spinal canal for lesions higher than the second lumbar disk is desired, it is necessary to place the head of the patient at the foot of the table, because the extreme Trendelenburg cannot be obtained when the patient is in the opposite position. The height to which the examination is carried will of course depend on the suspected level of the disease, but in all cases of sciatica the examination should be carried to the tenth or eleventh dorsal vertebra. The entire cauda equina and the conus medullaris should be completely examined. It will be noted that when the head of the prone patient is lowered to the extreme Trendelenburg position the flow of iodized oil will slow down as it reaches the conus medullaris. This slowing down of the oil is due less to the sudden change in the size of the structures of the spinal canal than to variation in its curve. The anterior lordotic curve of the lumbar spine reverses to the kyphotic curve of the dorsal spine; thus the incline of the oil is changed. In addition to the delay often noted at the conus medullaris, there is a tendency for the oil to break into small globules, and these may split into one or two streams flowing down one or both sides of the canal. An attempt should be made to prevent this breaking up of the oil by reducing the angle of the Trendelenburg position. It is obvious that particles of iodized oil may pass around small filling defects, whereas the bolus or mass of the entire amount would show these defects well. The small droplets can be brought together as one mass by simply bringing the patient to the upright position. If the dorsal or cervical areas are to be examined, it is important that the oil be carried toward the cranium with the patient lying prone on the table and the cervical spine held in extreme hypertension. The head can be maintained in this position by placing pillows underneath the chin. It is important that the position be maintained, especially when the oil enters the cervical area, to prevent the oil from reaching the cranial cavity. The patient should not be placed in a more nearly vertical position than is necessary to cause the oil to flow toward the head, because, even with the neck in extreme hyperextension, the oil will sometimes flow into the cranial cavity. If during the progress of the iodized oil from the sacrum to the cranium, apparent filling defects are noted, an effort should be made to obliterate them by manipulation of the oil upward and downward

and from side to side. The filling defect must be constant. Often the oil will separate into an hourglass shape as it crosses the levels of the disks, particularly in the lower dorsal and upper lumbar areas. A symmetric, smooth hourglass shadow is rarely due to rupture of the intervertebral disk. It is more likely due to a sudden change in the angle of the incline of the flow of iodized oil, the hourglass shape of the oil being due to both the viscosity of the oil and the difference in the rate of flow of the upper and lower halves of its mass. Hourglass constrictions can be made to disappear as the rate of flow of the entire mass of iodized oil is increased by a more rapid increase in the angle of descent. The physical principles involved may be compared to that involved in pouring thick liquid out of a small-mouthed vessel or in the stretching and separation of taffy candy. The extent and degree of any filling defect is of course best demonstrated when the maximum amount of oil is in contact with it.

It must be borne in mind that complete filling of the spinal subarachnoid spaces at any level except in the sacral cul-de-sac is impossible. When the patient is face down the oil gravitates toward the anterior aspect of the spinal canal and has a relatively shallow level. When the patient is on his back all the oil gravitates to the posterior aspect of the canal and again finds a level. If the entire canal is to be examined it is necessary that the patient be rotated in all positions under roentgenoscopic observation and the flow of the iodized oil observed in these positions. Fortunately, ruptures of the lumbar intervertebral disks are nearly always visible when the patient is examined in the face-down position with the oil equally divided above and below the involved disk. In some cases filling defects due to ruptured disks are so small that they are seen only in the oblique view, and even more rarely the lateral view is of benefit. When the defect is seen only in the lateral view it is seldom of clinical importance.

THE CHARACTERISTIC IODIZED OIL DEFECT

It is beyond the scope of this paper to include a complete roentgen description of the mechanism and variations in the filling defects produced by ruptures of the intervertebral disk. Robinson and I have already done this in our original presentation,[4] which has been confirmed by others. Only typical examples of each type of ruptured disk in the lumbar area are herewith presented:

4. Hampton, A. O., and Robinson, J. M.: The Roentgen Demonstration of Rupture of the Intervertebral Disk into the Spinal Canal After the Injection of Lipoidol, with Special Reference to Unilateral Lumbar Lesions Accompanied by Low Back Pain with "Sciatic" Radiation, Am. J. Roentgenol. **36**:782-803, 1936.

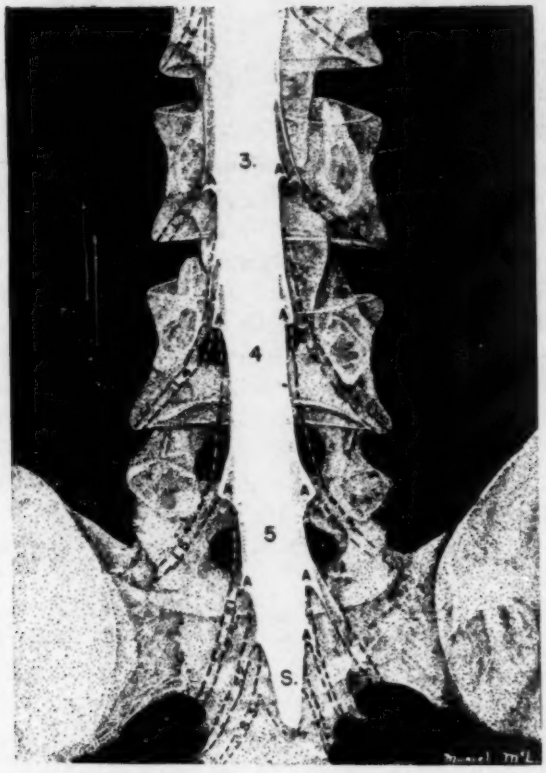

Fig. 1.—Drawing of the normal lumbar subarachnoid space filled with iodized oil. This is a composite of numerous roentgenograms, and the nerve roots are drawn in their anatomic locations.

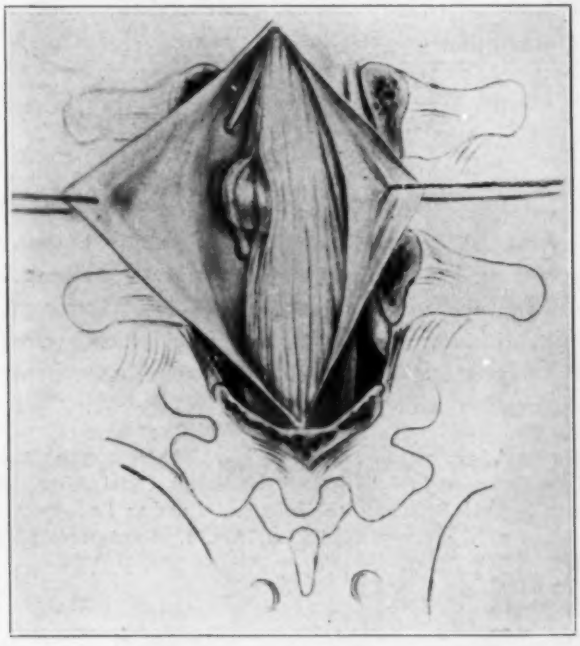

Fig. 2.—Rupture of the fourth lumbar disk exposed by opening the dura.

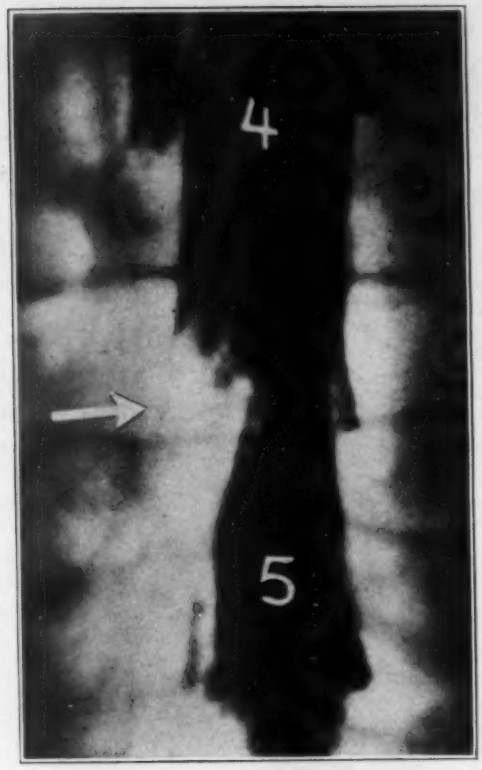

Fig. 3.—The characteristic filling defect of unilateral rupture of the fourth lumbar disk.

Fig. 4.—The most common filling defect produced by unilateral rupture of the fifth lumbar disk.

Fig. 5.—Failure to demonstrate rupture of the left side of the fifth lumbar disk.

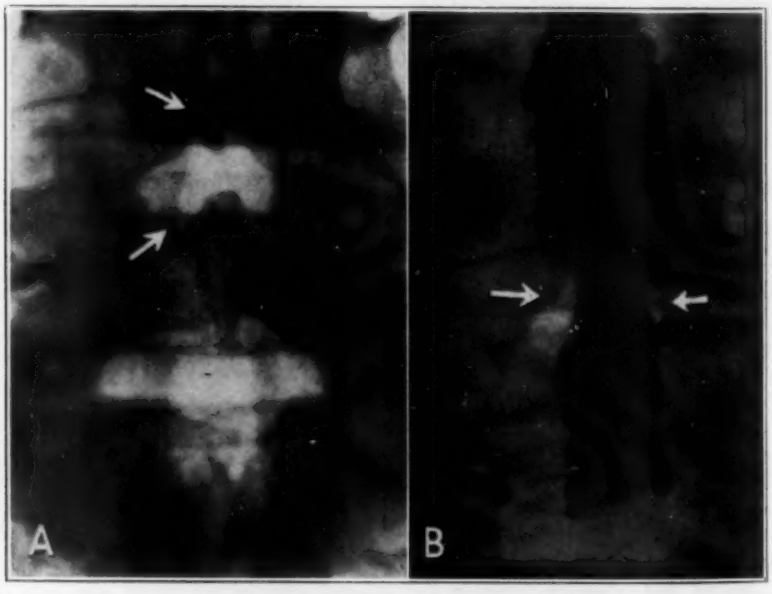

Fig. 6.—Comparison of an air (*A*) and an iodized oil (*B*) myelogram. Rupture of the fourth lumbar disk extends across the midline.

Figure 1 illustrates the normal lumbar subarachnoid spaces when completely filled with iodized oil. The course of the nerve roots has been drawn in, and each is labeled. Asymmetric filling of the root sheaths is a normal variation. It should be noted that the first sacral nerve crosses the fifth lumbar disk outside of the shadow of the iodized oil and that it is therefore possible for a rupture of the fifth lumbar disk to press on the root of the first sacral nerve without its being demonstrable by myelography. All the other nerves of the cauda equina cross the area of the disk within the shadow of the iodized oil, and for this reason pressure on these roots by a ruptured disk should always be demonstrable.

Figure 2 illustrates the mechanism of the filling defect produced in the subarachnoid spaces at the level of the fourth disk. Note that the lesion is in an anterolateral position, is about 1 cm. in diameter and elevates and displaces the more lateral nerve roots. Such ruptures of the fourth lumbar disk always press on the root of the fifth lumbar and perhaps on the first sacral nerve.

Figure 3 illustrates typical rupture of the fourth disk. The serrated upper margin corresponds to the compressed roots of the fifth lumbar and the first sacral nerve. It should be noted that the defect begins at the inferolateral margin of the lamina of the fourth lumbar vertebra, being adjacent to the posteroinferior articulating facet (compare fig. 2).

Figure 4 illustrates a typical rupture of the fifth lumbar disk. As has been pointed out, such defects are smaller, because the iodized oil–containing area does not extend as far laterally as the mass of the ruptured disk.

Figure 5 is a normal myelogram of the areas of the fourth and the fifth lumbar disk, but a rupture of the fifth lumbar disk was found at operation. There have been 2 such examples in the present series of cases.

In figure 6*A* air has been injected into the lumbar subarachnoid spaces and a filling defect is demonstrated opposite the fourth lumbar disk. This filling defect is indistinct and does not show the characteristics of the iodized oil myelogram (fig. 6*B*).

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INTRASPINAL PROTRUSION OF INTERVERTEBRAL DISKS

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PROTRUDED INTERVERTEBRAL DISK WITH COMPRESSION OF NERVE ROOT AND SPINAL CORD

Since the syndrome of protruded intervertebral disk became established, it has been diagnosed more and more frequently, not alone by the neurologist and orthopedist but by the general practitioner. It has been only within the last few years that a clinical diagnosis could be made of posterior protrusion of an intervertebral disk into the spinal canal, with subsequent compression of the spinal cord or of one or more nerve roots, and yet today it is a diagnosis that can be made in a high percentage of cases by any up-to-date physician. The information which has been collected, analyzed and correlated in the clinics of this country and given freely to the medical profession, by means of publications in medical journals and lectures before medical societies, has served to alleviate a great deal of suffering and to restore many workers to their former fields of usefulness after more or less prolonged periods of disability. The economic saving in time and money is inestimable.

For the sake of argument one might ask if there is not an increase in the number of persons who are undergoing operation for a condition that a few years ago was treated mostly by nonoperative methods. It is our feeling that this is definitely true. We also feel that the change in treatment, founded as it is on sound anatomic, pathologic and surgical principles, is fully justified, and further, since the patients in carefully studied and selected cases are restored within a relatively short time to useful activity by the employment of the proper surgical treatment, there seems to be no justification for the older methods of so-called conservative treatment, which have to be carried on indefinitely, with a period of two weeks to three months of rest in bed either at home or in a hospital every year.

From the Section on Neurosurgery (Dr. Love) and the Section on Neurology (Dr. Walsh), the Mayo Clinic.

Immediately, we wish to emphasize that we strongly favor and urge a trial period of so-called conservative treatment, unless there is gross evidence of damage to the central nervous system, before the undertaking of neurosurgical methods for the relief of pain in the neck, shoulders, back or lower extremities. A period of observation on conservative treatment will indicate to the careful observer, in many cases, that there is an underlying lesion of the spinal cord or of a nerve root which must be attacked centrally.

We are still convinced that the intervertebral fibrocartilaginous disks protrude posteriorly into the spinal canal as the result of unusual stress or strain applied to the vertebral column. This stress may be the result of a single outstanding injury or it may be the result of repeated injuries of varying degrees of severity.

In an analysis of 500 consecutive cases in which operation was performed at the Mayo Clinic for protrusion of one or more intervertebral disks, we have learned that 58 per cent of the patients gave a history of a specific injury to the back. Many patients, when they give their history for the first time, fail to mention any past injury; however, when more closely questioned regarding accidents and injuries many of them recall some episode followed by backache which subsided after a reasonable length of time. Most of these persons had not connected their presenting chief complaint of backache or sciatic pain with the injury. This is true particularly if there has been a long interim of freedom from pain. An analysis of our series of cases brings out the point to which we have called attention previously, that a high percentage of patients give a history of intermittency of symptoms. Eighty-four per cent of our 500 patients had intermittent symptoms. Whether this intermittency is due to vascular changes in the protruded portion of the disk as suggested by Deucher and Love [1] or to degeneration and interruption of pain fibers as a result of compression of the nerve root by the protruded body as suggested by Adson [2] or to a return of the protruded fragments to within the center of the intervertebral space, as has been suggested by many, is not known. That intermittency is a characteristic finding in these cases is noteworthy, and it serves as a useful criterion in distinguishing between root pain caused by a protruded disk and that caused by an intraspinal neoplasm, which usually is marked by definite progression of symptoms and signs.

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1. Deucher, W. G., and Love, J. G.: Pathologic Aspects of Posterior Protrusions of the Intervertebral Disks, Arch. Path. **27**:201-211 (Feb.) 1939.

2. Adson, A. W.: Personal communication to the authors.

Protrusion of any intervertebral disk may occur, as far as we know, but in the vast majority of cases the protrusion occurs in the lumbar region of the spinal canal. Approximately 96 per cent of our 500 patients had lumbar protrusion (fig. 1). This is an important fact, which helps to make an otherwise extremely complicated problem comparatively easy to solve.

Protrusions in the cervical and thoracic regions of the spinal canal, because of the limited amount of space between the spinal cord and the bony canal, resemble more closely intraspinal neoplasms, and they are usually detected more promptly than those in the lumbar region, where the cauda equina has such freedom of motion. No lesion can

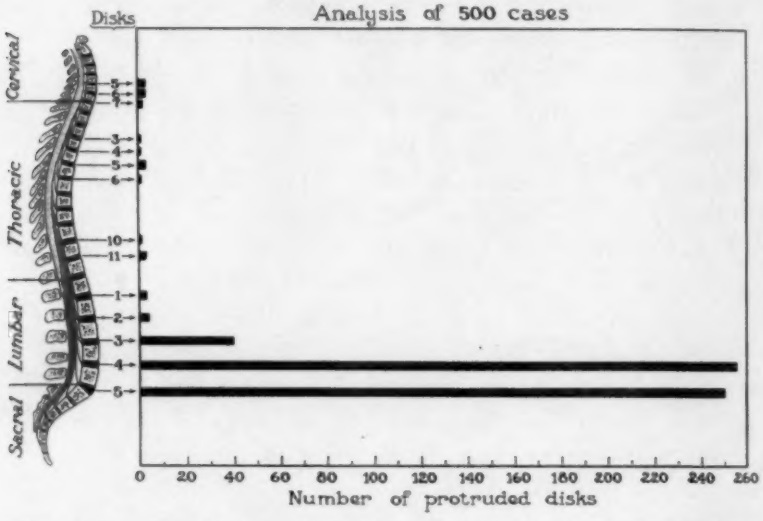

Fig. 1.—Frequency of protrusion of intervertebral disks at various levels in the spinal column.

assume much size in the cervical and thoracic regions of the spinal canal without interrupting some nerve pathway and thus calling attention to a compressive lesion. However, in the lumbar region a mass may be large before any conduction system is affected.

Men, it would seem, are more unkind to their backs than are women, for in our series there were 358 men and only 142 women who were operated on because of protruded disks. This cannot be taken, we feel, to indicate that the male's back is weaker than that of the so-called weaker sex. It means probably that the discrepancy is due to the etiologic factor, trauma, which has a greater chance to exert itself among men, who ordinarily do most of the heavy lifting and straining

and who, in industry, are more likely to be injured. It is interesting to note also that the average age of our patients at the time of operation was 40 years. When the histories are analyzed further and it is noted that most of the patients have had intermittent symptoms for several years before the true cause of the disability was discovered, it will be seen that the protrusion occurred at an earlier age and at a time when a man probably is doing his most strenuous work and is most likely to sustain an injury.

The most common symptoms and signs and those which were of greatest value in arriving at a clinical diagnosis of protrusion of a lumbar disk were unilateral sciatic pain, which occurred in 78 per cent of cases, and bilateral sciatic pain, which was present in 16 per cent. In the other 6 per cent, backache alone or extension of pain elsewhere than along the course of the sciatic nerve occurred. Twenty-four per cent of the patients complained of pain which interfered with sleep at night. This is an important symptom when present. It is particularly suggestive of a lesion of a nerve root, but it is much more common in cases of intraspinal neoplasm than in cases of protruded disk. Another indication of involvement of a nerve root or of a radicular type of pain is accentuation of the pain on coughing, sneezing or straining at stool. Such accentuation occurred in 64 per cent of our cases. Paresthesias in the dermatome supplied by the compressed nerve root are of value in the diagnosis and localization of the protrusion. Paresthesias occurred in 50 per cent of our cases. On the other hand, sphincteric disturbance occurred in only 4 per cent. When such disturbance occurs, it usually means that a very large lesion is present and often a complete subarachnoid block, which is uncommonly associated with protruded disk.

The three neurologic signs which continue to be the most helpful in the diagnosis of protrusion of a lumbar disk are Lasègue's sign, positive in 84 per cent of cases, sciatic tenderness, present in 64 per cent, and diminution or absence of the achilles reflex on the side of the pain, noted in 60 per cent.

In only 25 per cent of cases was there any muscular weakness; sensory loss was detected in only 21 per cent. This is not difficult to understand in the light of the fact that the protrusion usually is small and compresses only one nerve root. Examination gave objectively negative results neurologically in 20 per cent of cases except for a positive Lasègue sign or sciatic tenderness or both. All patients suspected of having a protruded intervertebral disk should undergo a diagnostic lumbar puncture, so that the hydrodynamics of the spinal fluid may be

studied and a specimen of the fluid obtained for careful analysis. As has been stated, a protruded disk rarely produces subarachnoid block, particularly a disk in the lumbar region of the spinal column. The detection of such a block, therefore, would be suggestive of greater likelihood of an intraspinal neoplasm. The surgical treatment of such a condition requires essentially the same procedure, although in our hands the operation for the two conditions has been modified considerably. This subject will be dealt with under the heading "Surgical Technic for Protruded Intervertebral Disk."

The most important finding in the analysis of the spinal fluid in such cases is the total protein content of the spinal fluid. In the entire series, 40 per cent of the patients had less than 40 mg. of total protein per hundred cubic centimeters of spinal fluid in the specimen submitted for analysis. This percentage of patients with normal or low values for total protein is higher than in the series of 300 cases previously reported.[3] This can be explained, we believe, on the basis of a changed technic for diagnostic lumbar puncture. For about a year we have been puncturing the spinal canal at the interspace between the first and second lumbar vertebrae or between the second and third lumbar vertebrae; we obtain a specimen of spinal fluid for examination, and at the same time we replace the fluid in the caudal sac with air in order to obtain a spinogram or visualization of the lumbar canal. In this way we have been able to confirm the clinical diagnosis of protruded disk in a very high percentage of cases by means of one lumbar puncture, which obviates repeated punctures and shortens the examination considerably. However, since in most instances the lumbar protrusion occurs at the fourth or fifth lumbar interspace, we are puncturing the meninges and are obtaining our specimen of fluid at a greater distance from the lesion than when we tried in all cases to puncture as low in the spinal canal as possible.

ROENTGEN CONFIRMATION OF THE CLINICAL DIAGNOSIS OF PROTRUDED INTERVERTEBRAL DISK

In our earlier work on protruded disks, the diagnosis was confirmed prior to operation by roentgenoscopic and roentgenographic examination of the spinal subarachnoid space after injection of radiopaque oil.[4] The accuracy of the detection or the exclusion of intraspinal lesions by means of this substance in the hands of the roentgenologists at the clinic was

3. Love, J. G.: Protruded Intervertebral Disk (Fibrocartilage), Proc. Roy. Soc. Med. **32**:1697-1712 (Oct.) 1939.

4. Love, J. G., and Camp, J. D.: Root Pain Resulting from Intraspinal Protrusion of Intervertebral Disks: Diagnosis and Surgical Treatment, J. Bone & Joint Surg. **19**:776-804 (July) 1937.

high, greater than 90 per cent. Because of the fact that radiopaque oil is absorbed slowly from the subarachnoid space, we dislike to use it in questionable cases, especially if the patients are not to have an operation. More recently, we have employed air in diagnosing lumbar protrusions. Air is a great addition to our diagnostic means because of its absorbability, but the observations made with it, according to Camp,[5] do not compare favorably in accuracy with those made by means of radiopaque oil.

If a study in which air is used (spinogram) does not reveal the defect of a protruded intervertebral disk, it by no means excludes the possibility that such a lesion exists. Even roentgenoscopic examination of the spinal subarachnoid space after the introduction of iodized poppyseed oil 40 per cent may fail to reveal a defect when a characteristic protrusion with its usual symptoms is present. This failure may be due to an anatomic abnormality of the cul-de-sac, such as congenital shortening, or it may be due to the fact that the protrusion lies too far laterally out in the foramen of exit of the spinal nerve. In 1 or 2 cases of our series it was impossible to explain the absence of a characteristic defect. When all findings point to the presence of a protruded disk and when the diagnosis cannot be confirmed roentgenologically, we feel that we are justified in advising an exploratory operation, for, in our experience, this can be done without the sacrifice of any bone and with a risk of less than 0.5 per cent, and the accuracy of our clinical diagnoses is extremely high. The following case history illustrates the point.

REPORT OF A CASE

A graduate nurse 25 years of age was suffering from intractable sciatic pain on the left side, which was aggravated by movement, coughing, sneezing and straining. Orthopedic examination by Dr. Meyerding revealed no cause of the severe pain. Neurologic examination gave entirely negative results except for tenderness along the course of the left sciatic nerve and inability to raise the leg, when held straight, more than 5 degrees from the horizontal. Air studies and spinograms gave negative results. Roentgenoscopic and roentgenographic examinations of the spinal canal disclosed no defect (fig. 2), and yet the pain of which the patient complained was so characteristically rootlike in type that we advised an exploration for a protruded disk. The patient had six lumbar vertebrae, the last one of which was fused with the sacrum. Since pain was on the left side, we knew that the lesion must be on the same side, and since with true sciatic projection of pain the protrusion is most likely to be at one of the last two interspaces, we exposed the ligamenta flava opposite the last two interspaces on the left. Immediately it was noted that the ligament between the fifth and sixth vertebrae was abnormally thick and fibrous. When it was resected, edema

5. Camp, J. D.: The Roentgenologic Diagnosis of Intraspinal Protrusion of Intervertebral Disks by Means of Radiopaque Oil, J. A. M. A. **113**:2024-2029 (Dec. 2) 1939.

of the nerve root, characteristic of a protrusion of the underlying disk was noted (fig. 3). The fragmented and protruded portion of the disk (fig. 4) was removed, with release of all pressure on the nerve root. Immediate relief of all pain

Fig. 2.—Anteroposterior roentgenogram showing a normal configuration of the caudal sac as outlined by radiopaque oil in a patient in whom a protruded fifth lumbar disk was found and removed.

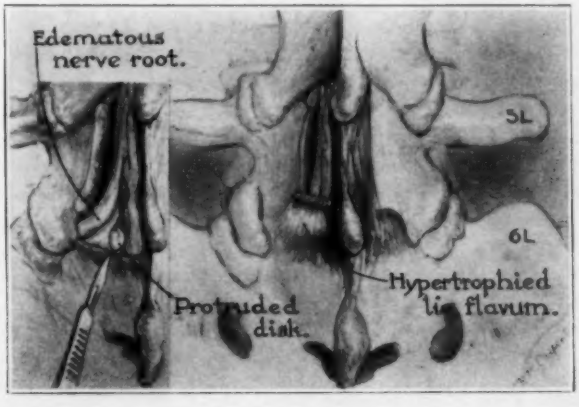

Fig. 3.—Drawing representing the protruded disk which was encountered at operation in spite of the negative findings on roentgenologic study with radiopaque oil illustrated in figure 2.

occurred, and sedatives and narcotics, which had been required in large doses prior to operation, were no longer needed. The patient left the hospital on the twelfth day after the operation and returned to her nursing duties three months later.

SURGICAL TECHNIC FOR PROTRUDED INTERVERTEBRAL DISK

Every patient suffering from backache with or without "sciatica" is not a subject for intraspinal investigation, nor is such a one necessarily to be suscepted of having a protruded intervertebral disk. Those who definitely need investigation to confirm or disprove the suspicion that a protruded intervertebral disk is the cause of their symptoms are the patients who have what in the past has been considered as intractable backache and "sciatica."

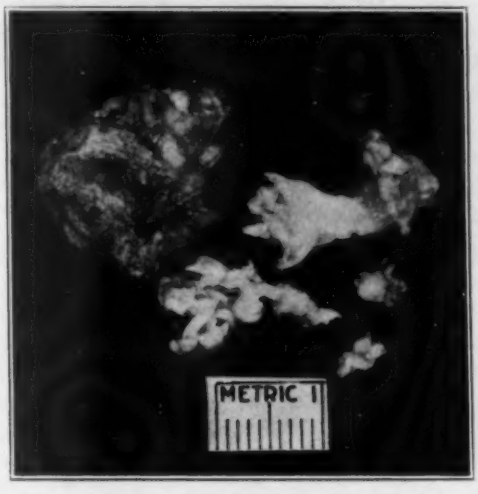

Fig. 4.—The darker structure represents the hypertrophied ligamentum flavum; the brighter pieces of tissue are the fragmented protruded portions of the intervertebral disk removed at the time of operation.

There are many pains in the back and legs which respond satisfactorily and often promptly to rest, either partial rest or complete rest in bed; others require physical therapy, with or without strapping or support to the back. The more severe conditions may be due to metabolic disturbances, tumors of peripheral nerves, intraspinal neoplasms or tumors of bone. Poisoning with alcohol or the heavy metals may also result in "neuritis" which for a time may be difficult to elucidate. In any case, a careful and thorough physical examination with roentgenograms of the spinal column and pelvis should be made.

When a diagnosis of protruded intervertebral disk is made and the surgical method of treatment is decided on, the operation should be performed by some one familiar with intraspinal surgery. The large

protrusions that produce partial or complete subarachnoid block are usually easily handled, but the smaller, more common protrusions are at times difficult to find even after they have been demonstrated roentgenographically, and hemorrhage from the extradural vessels may be extremely troublesome.

The anesthetic agent of choice is ether administered by the open drop method. If there is any question regarding the patient's thorax or upper respiratory tract as far as recent infection or tuberculosis is concerned, we prefer to use pentothal sodium (sodium ethyl-1-methylbutylthiobarbiturate) intravenously or spinal analgesia. The patient is then placed on his side, instead of in the prone position which is usual for laminectomies. With pentothal sodium injected intravenously or with spinal analgesia, the excursions of the thorax are so slight that it would be unwise to have the patient lie thereon. Because pentothal sodium acts quickly, the patient should be on the operating table, prepared and draped for operation, before the venipuncture is made and before administration of the drug is begun. Suitable preliminary medication such as pentobarbital sodium, morphine sulfate and scopolamine hydrobromide in full hypnotic doses, given sufficiently early (before the patient is placed on the operating table) decreases the amount of pentothal sodium that is required. Some experience in administration of the drug is essential for smooth anesthesia.[6] The only untoward effect of such anesthesia is a slight increase in bleeding from the muscles of the back. This is due to the well known vasodilating effect of pentothal sodium.

The operation may be done with the aid of paravertebral block, but in the majority of cases an anesthetic which blocks all sensory pathways in the lumbar region is to be desired. Most of the patients have had about all the pain they can stand, and they do not enjoy multiple insertions of a needle in the back; furthermore, when the involved nerve root is manipulated at the time of exposure of the protruded disk, considerable pain is produced even though the intradural portion of the nerve is bathed in procaine hydrochloride. Even under general anesthesia, it is not uncommon for the the patient to move or tighten his muscles when the nerve is manipulated. Under general anesthesia, however, there is amnesia for this pain. In this connection we should like to record an interesting if unexplainable clinical observation: A few days after operation, gauze packs which have been placed along a nerve root at operation are removed. One of us (Love) has observed that earlier, when we used morphine sulfate in relatively large doses one half to three quarters of an hour before pulling the pack, the patient not only had excruciating pain while traction was being exerted on the gauze but was likely to

6. Adams, R. C.: The Present Status of Intravenous Administration of Pentothal Sodium in Institutional and Private Practice, Canad. M. A. J. **38**:330-337 (April) 1938.

complain of severe pain for a day or two thereafter. Since the introduction of pentothal sodium, used intravenously for this purpose, the patient not only is not conscious of the pain at the time of removal of the pack but does not have pain after he awakens, although he may have become tense when the pack was withdrawn.

Operative exposure of a protruded disk should be as accurate and as limited as possible; however, adequate room for the removal of all fragments is essential. The articular facets and pedicles should be preserved. No more bone should be removed than is absolutely essential for visualization and removal of the protruded portion of the involved disk. Whenever possible, a modified type of laminectomy should be employed; that is, instead of the removal of two or three pairs of laminas, the removal of a portion of one pair should suffice in most cases. During the past several months it has been the practice of one of us (Love) to perform what has been designated as "partial laminectomy"; that is, no neural arch is interrupted. Instead, the margins of the laminas are removed. If there has been pain on one side only, the protrusion is typical and lateral and the ligamentum flavum is not markedly thickened on the opposite side; then, hemilaminectomy can be performed with satisfaction. At times, owing to great thickening of the ligamentum flavum and a listing of the patient away from the side of the protrusion, the lesion can be removed without the removal of any bone. It has been possible to remove the protruded disk in more than 20 cases without the removal of any bone from the spinal column. Theoretically, the less bone removed, the stronger the back will be postoperatively, and if at any subsequent time fusion should be required, it can be done with greater ease if none of the spinous processes or laminas has been removed.

For removal of a protruded intervertebral disk the patient is hospitalized the afternoon before operation. He is given a light supper, and before he goes to sleep, an enema of soap suds. If the patient is in severe pain, morphine sulfate or pentobarbital sodium is ordered, so that a good night's rest can be obtained. The next morning, all food and liquids are withheld and the patient is given hypodermically $\frac{1}{6}$ grain (0.01 Gm.) of morphine sulfate; on call to the operating floor he is given $\frac{1}{150}$ grain (0.00043 Gm.) of atropine sulfate. If the anesthetic is to be pentothal sodium, 1½ or 3 grains (0.1 or 0.2 Gm.) of pentobarbital sodium is given on the evening before operation and is repeated on the morning of operation about one hour before the patient is called to the operating room. On call to the operating room, morphine sulfate and scopolamine hydrobromide are administered hypodermically. If ether is to be the anesthetic agent, morphine and atropine are the only drugs given on the morning of operation. During the period of induction, nitrogen monoxide and oxygen are used; then ether is administered. When the patient is

asleep, an intratracheal tube may be inserted to facilitate easy, smooth respiration while the patient is lying prone with the neck turned to one side. The Magill intratracheal tube is particularly useful if the patient has a short thick neck.

After insertion of the intratracheal tube (this is done while the patient is still on a ward cart), the patient is placed on the operating table in the prone position. The torso is supported by the shoulders and pelvis, as this further facilitates breathing. Two large rolled pillows are placed longitudinally on the table so that the upper ends extend beyond the shoulders and rest under the clavicle. The lower ends of these pillows are crossed by a large flat soft pillow, which crosses the abdomen at the level of the iliac crests. The latter pillow, by adjustment, can be used to help flex the patient's back, a procedure which separates the spinous processes of the lumbar vertebrae and facilitates laminectomy. The skin is carefully shaved, not only that portion in the region of the contemplated incision but also the skin of the entire back which might be covered by the postoperative dressing and adhesive plaster. This is done not alone for aseptic reasons but also to avoid the discomfort attendant on removal of the dressings, particularly adhesive tape.

The skin is then thoroughly washed with ether and then with alcohol. Afterward, two coats of tincture of merthiolate are applied. The merthiolate should be used generously and widely. It is our feeling that wide application is good, for during any surgical procedure, particularly in warm weather, perspiration is likely to soak through the sterile drapes. If a generous application of antiseptic is on the skin, there is less likelihood of contamination of the wound.

When the drapes are placed they should not be more than 1½ inches (3.8 cm.) to either side of the spinous processes, and only sufficient skin to accommodate the length of the proposed incision should be exposed. The incision is made straight in the midline extending across the tips of two spinous processes. The muscles (erectores spinae) are reflected from the bone (spinous processes and laminas) subperiosteally (fig. 5 *e*). This minimizes bleeding and trauma to the muscles and facilitates closure. If the operation is to be a hemilaminectomy, the muscles need to be reflected only on one side; however, if the wound is short, the self-retaining retractors work best if all of the prongs are at an equal depth in the wound, and then it often is advantageous to view the other side of the ligamentum flavum, which may be hypertrophied and may therefore require resection.

It is not necessary to strip the muscles widely or to undercut or crosscut them. The packing of gauze sponges between the bone and the reflected muscles not only controls small bleeders but also irons out the muscles, so to speak, and when the self-retaining retractor is inserted,

it often is surprising to see the large amount of exposure obtained. While the gauze is packed in the depths of the wound, the cutaneous and subcutaneous bleeders which have been caught with points are electrocoagulated. It is nearly impossible to ligate these bleeders, and catgut knots are not well absorbed when placed superficially in the back. When the superficial bleeding has been controlled, the gauze sponges are removed from the depths of the wound and the Adson self-retaining laminectomy retractor (fig. 5 *d*) is placed so as to hold the muscles away from the spinous processes and midportions of the laminas. If a bilateral or partial laminectomy is to be done, the tips of the spinous processes are sheared off with a cutting forceps (fig. 5 *f*). If the operation is to be a hemilaminectomy, none of the spinous processes is

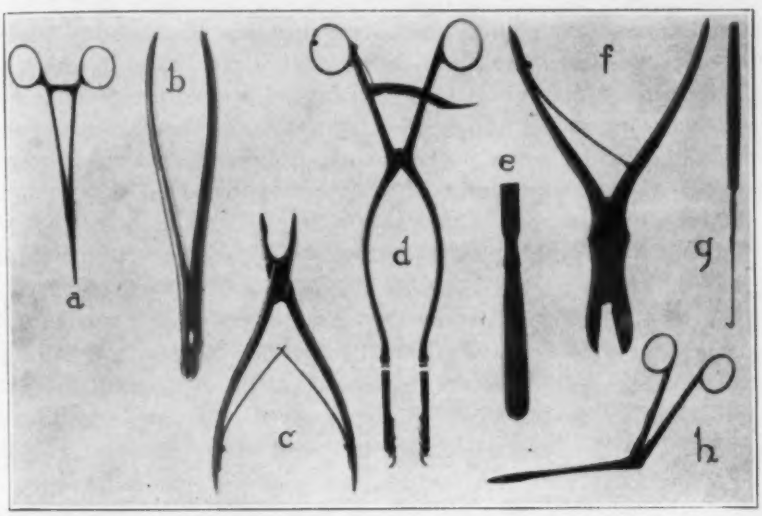

Fig. 5.—Special instruments used in the removal of a protruded intervertebral disk: *a*, Ochsner's 6¼ inch (15.6 cm.) mortis joint forceps; *b*, Adson's curved gouging rongeur; *c*, Adson's laminectomy straight rongeur; *d*, Adson's laminectomy retractor; *e*, Adson's laminectomy chisel; *f*, double action Liston cutting forceps; *g*, Love's nerve retractor, and *h*, Grünwald nasal ethmoid forceps.

removed. At most, two spinous processes are sacrificed. The portions of laminas to be sacrificed are removed with a heavy duty bone-biting forceps or rongeur (fig. 5 *b*). In a hemilaminectomy the lamina can be removed best with a straight single-acting rongeur (fig. 5 *c*), as large instruments cannot be inserted between laminas. The bone should be removed from around the ligamentum flavum so that the size, color, resistance and thickness of the ligament can be noted.

We feel confident that in the past many abnormal ligaments have been removed with rongeurs without their abnormality having been

noted. When the ligament is dissected free, it should be grasped with a forceps (fig. 5 *a*) and then be resected as widely as possible in order to remove any of the usually thickened ligament which might compress the nerve root posteriorly. By this time, the enlarged, edematous, discolored and displaced nerve root should have been visualized. The involved nerve is frequently several times larger than normal, is reddish to purplish and is displaced posteriorly and laterally or at times mesially. Retraction of the nerve root will reveal the characteristic posteriorly protruded fibrocartilaginous mass or protruded disk. The protruded portion should be removed extradurally, and even if the dura mater is to be opened for the removal of radiopaque oil, this should be postponed until the protruded portion of the disk has been removed. There are three good reasons for this: first, there is less bleeding, and it is more easily controlled if it occurs; second, there is less likelihood of trauma to the already injured nerve root if the cerebrospinal fluid is within the dural sac acting as a buffer, and, third, if one should accidentally open an inflammatory mass such as tuberculous abscess, the meninges would not be contaminated. Pus on the outside of the dura mater is relatively innocuous whereas pus in the subarachnoid space is likely to result in meningitis and death.

Many of the protruded bodies consist of completely fragmented fibrocartilage which has ruptured through the posterior longitudinal ligament; as soon as the involved nerve root is retracted (fig. 5 *g*) the fragments need only to be picked from the wound. Others are still held partly in check by the posterior longitudinal ligament, and this must be opened before the fragments can be removed. At times the ligament is so thin that the bayonet forceps can easily be pushed through the dome of the mass, and then the protruded body is removed. At other times incision of the portion of ligament that overlies the protruded disk is necessary. A ureteral knife serves this purpose well. Occasionally the protruded body is calcified or ossified, and then it is necessary to use a curet or rongeur for its removal.

Rarely is it necessary to proceed transdurally in order to remove a protruded disk. Some midline protrusions, which are relatively infrequent, particularly those which have produced a block and paraplegia, are so large and have caused so much edema and enlargement of the cauda equina on both sides of the spinal canal that they are best removed transdurally. The dura mater is incised posteriorly over the site of the protrusion, the cerebrospinl fluid is allowed to escape, and then the spinal canal proximal and distal to the protruded mass is packed off with cottonoid strips. This is done in case there is bleeding when the dura mater is incised anteriorly. The dura mater over the dome of the pro-

trusion is then incised. Again the protrusion may have ruptured through the posterior longitudinal ligament, or it may be necessary to incise this ligament before the protruded disk can be removed. It is essential that all fragmented cartilage be removed. The use of a nasal forceps (fig. 5 *h*) facilitates the removal of small fragments that otherwise might be overlooked. It is not necessary to suture the dura mater anteriorly, but the posterior incision should be closed with a continuous suture of fine silk.

If radiopaque oil has been used in confirming the diagnosis of a protruded disk prior to operation, the radiopaque oil should be removed from the subarachnoid space before the wound is closed. If the protruded body has been removed extradurally, the dura mater and arachnoid should be opened with a ureteral knife for a distance of 1 cm. and the oil removed. While the operation is being performed, the patient's head and shoulders should be elevated, by lifting the head of the operating table, so that the oil will be collected in one mass at or near the site of the protrusion. The oil is best removed by means of a suction apparatus which is standard equipment in all neurosurgical amphitheaters. Care should be taken lest one or more roots of the cauda equina be caught by the sucker tip. This would result in unnecessary trauma and possibly in residual disability. At times, removal of the oil may be facilitated by irrigating the subarachnoid space proximal and distal to the most dependent point, where the oil tends to accumulate, with physiologic solution of sodium chloride at a temperature of 100 F. (37.7 C.). The saline solution is injected through a no. 10 French urethral catheter by means of a bulb syringe. Whenever possible, the operative wound should be closed without drainage. The muscles (erectores spinae) are sutured together across the midline with interrupted sutures of no. 1 chromic single-stranded catgut. The fascia is sutured in a similar fashion. The edges of skin are then approximated with a continuous silk or dermal suture. Occasionally a better closure is obtained if catgut is used to suture the subcutaneous layer, particularly if a long incision has been employed.

At times bleeding from the extradural vessels, particularly from the veins, is troublesome and some special means is necessary for its control. All laminectomy wounds should be dry before they are closed, lest a postoperative hematoma form and result in serious complications, such as paralysis. Often the simple expedient of placing a cottonoid strip on the extradural vessel and applying suction is sufficient to control the bleeding. At times a small pledget of muscle obtained from the erector spinae and applied to the bleeder suffices. At other times bleeding cannot be controlled by any of these methods. The vessel may then be

sought after and one or more silver clips applied to obliterate its channel. These vessels are often elusive, and considerable time may be lost while hunting for the bleeding point. Coagulation of the bleeder with the electrosurgical unit is employed by some, but this method may result in injury to nearby nerve roots. The current may "jump" to a nerve root, and this may not only injure the nerve root but also it is likely to make the patient move because of stimulation of the muscle or muscles supplied by the irritated nerve root; this often increases the bleeding and obscures the surgical field. In our experience the most satisfactory way to control extradural bleeding is with plain gauze 1 inch (2.5 cm.) wide. The gauze is packed extradurally against the bleeding vessel and then suction is applied to a wet cottonoid strip placed over the gauze. In a short time, all bleeding ceases; then the cottonoid strip is removed, and the muscles are closed around the gauze strip. Such a gauze strip should not be disturbed for forty-eight to seventy-two hours.

After the operation but before the surgical drapes are disturbed, the skin near the incision should be washed with saline solution, and then a small gauze dressing moistened with alcohol should be applied over the line of suture; this dressing should be covered with a sterile soft absorbent (cotton) pad. The drapes are removed, and then the dressings are securely fixed in place with strips of adhesive tape. The tape should seal the upper and lower ends of the dressings to the skin, but the lower strip of tape should be kept as far away from the natal cleft as possible, to avoid contamination. The center and sides of the dressings, we feel, are best left unsealed. This permits air to get to the wound and allows evaporation of perspiration that forms under the dressing. If the cutaneous edges remain moist, they may macerate, and this would facilitate the development of infection.

POSTOPERATIVE CARE

The treatment of a patient following the removal of a protruded intervertebral disk is important, and we believe that it plays an important role in the restoration of the patient to an active useful life within a time that is consistent with good surgical judgment and well within the limits of the time required for convalescence from any major surgical procedure.

The patient is taken from the operating table to his room on a surgical cart. Care should be exercised to prevent chilling of the patient while he is wheeled along the corridors or transported to another floor by elevator. The bed to receive the patient should have been prepared and warmed. Boards are placed under the mattress to prevent sagging of the mattress and consequently of the patient's back. The patient is

placed in bed on his side, and pillows are placed against his back to prevent him from rolling backward onto his wound. A competent nurse should be constantly in attendance until the patient is fully awake and able to cooperate. Special nursing care is not required after the patient has regained consciousness.

When the patient becomes conscious and begins to complain of pain in the back at the site of the operation, he is given morphine sulfate hypodermically to control the pain. This should be repeated as often as every four hours for the first two or three days, if necessary. By this time, it is usually unnecessary to use any analgesic stronger than acetylsalicylic acid in doses of 5 grains (0.3 Gm.) each. It should be emphasized that no sedative should be given postoperatively until the patient is awake and is able to move his toes on command. It is essential that the patient's ability to move his toes and to recognize touch and pain in his extremities be checked frequently during the first few days following operation. If any diminution of this ability occurs, postoperative bleeding should be suspected, and the wound should be opened without delay. If hemorrhage has occurred, its prompt recognition coupled with removal of the hematoma should prevent the persistence of weakness or anesthesia. If a postoperative hemorrhage is not recognized, permanent damage may result from compression of the spinal cord or cauda equina.

During the first forty-eight hours the patient is turned every four hours by a group of nurses, but he is not allowed to lie on his back. Pressure against the wound is avoided until it is healed (about ten days). After forty-eight hours the patient is allowed to turn himself as often as he desires. To lie on one's side for four hours results in rather severe distress in the hips. This is largely avoided by permitting the patient to be turned when he becomes uncomfortable; in addition, the amount of sedatives required is kept at a minimum by such treatment. The patient's morale is improved when he realizes how much he can do alone. Avoidance of morphine is to be desired. The patients are allowed fluids after nausea has ceased and solid food as soon as desired, usually the next day. On the morning of the third day a simple soap suds enema is usually given. Care should be taken to avoid contamination of the dressing at the time of evacuation of the bowel, particularly if the operation was for lumbosacral protrusion, in which the dressing, of necessity, is placed low on the back and near the nates. If the dressing should accidentally be soiled, it should be changed immediately, and the wound should be painted with an antiseptic solution to avoid contamination.

The patient from whom a protruded disk has been removed without the removal of any bone is allowed to stand beside the bed or go to the bathroom the day following operation, if unable to void lying in bed.

Those who have suffered interruption of continuity of a neural arch ordinarily are catheterized after operation and every eight hours thereafter. If unable to void after three days of intermittent catheterization, an inlying urethral catheter is employed for continuous drainage until the patient is up and around, usually the tenth to twelfth day. The cutaneous sutures are removed on the tenth postoperative day, and the patient usually leaves the hospital by the twelfth day.

PROTRUDED INTERVERTEBRAL DISK AND FUSION

A few years ago patients who were being treated for protruded intervertebral disks were having bone grafting or fusion operations performed. Today such operations are comparatively infrequent. Naturally, the question arises as to whether or not fusion should be performed at the time of removal of the protruded disk.

There are certain definite indications for fusion on which orthopedic surgeons are agreed, there are conditions in which fusion is open to question, and there are conditions in which it is definitely contraindicated. It is our feeling that the patient should be considered individually and that treatment should be adapted to the particular indications which are presented in his case.

The patient who has a protruded disk and well developed spondylolisthesis should have fusion performed at the time of removal of the protruded disk. The patient who has associated spondylolysis probably should have fusion done at the time of surgical removal of the protruded disk. The patient who has extensive lumbosacral arthritis and a static type of backache in addition to a protruded disk and its resultant symptoms probably should have fusion done at the time when the protruded disk is removed.

However, fusion will not be found necessary or indicated in a high percentage of cases. The orthopedic surgeons of the clinic, Henderson, Meyerding, Ghormley and Macey, who see with us in the neurologic and neurosurgical departments every patient suspected of having a protruded disk, have found it necessary to fuse the spinal column in only 15 of more than 500 operations for protruded intervertebral disk.

Fusion not only is not indicated but is definitely contraindicated in many such cases. For the young person who has not reached maturity and whose bones are still growing, bone grafting of the spine is not ordinarily undertaken. We have removed protruded disks from several patients who were in their middle teens. For those of advanced years, fusion or any other surgical procedure which would require a prolonged period of immobilization in bed is contraindicated. We have successfully removed protruded disks from many who were in their late sixties

and early seventies. These patients usually have been allowed to get out of bed five or six days after operation in order to avoid pulmonary complications; this, of course, could not be allowed if fusion were performed.

EVOLUTION OF THE TECHNIC FOR REMOVAL OF PROTRUDED INTERVERTEBRAL DISK

Earlier in our experience with the surgical treatment of protruded intervertebral disk a comparatively extensive and time-consuming operation was performed. It seemed necessary to have a wide exposure of the involved nerve root and protruded disk. Usually, two and often even three pairs of laminas were resected (fig. 6), a procedure which is commonly employed for the removal of intraspinal neoplasms. From the first, however, we have maintained that the articular facets should be preserved. As our experience with this lesion increased, we found that the sacrifice of one pair of laminas sufficed to expose the involved nerve root and the underlying protruded body (fig. 7). We then modified the operation and performed a hemilaminectomy of one vertebra in cases of unilateral protrusion with unilateral symptoms (fig. 8). This operation was then modified and became what we call a partial laminectomy, namely, removal of only the margins of the laminas without interruption of a single neural arch (fig. 9). On Dec. 1, 1938, while we were carrying out an operation planned as a hemilaminectomy for a patient who had comparatively marked scoliosis toward the side opposite the lesion, we found that the protruded portion of the disk could be removed without the removal of any bone (fig. 10). No portion of the neural arch or spinous process was sacrificed.[7] By resecting the hypertrophied ligamentum flavum—such hypertrophy is an almost constant accompaniment of protruded disk—adequate exposure for removal of the fragment cartilage was obtained. After such an operation the roentgenograms of the spinal column appear exactly the same as those made prior to operation. In the illustration a silver clip placed in the center of the disk at the time of removal of the protruded part of the disk indicates the site of removal and confirms the statement that the spinal canal was entered without the removal of any bone (fig. 11). Such an operation requires a very short incision (fig. 12), a minimum of trauma to the muscles and a short period of anesthesia, and permits the patient to be up and around in a much shorter time than otherwise would be necessary. The shortening of the period in the hospital is a boon to the patient's morale and minimizes the economic strain that

7. Love, J. G.: Protruded Intervertebral Disks, with a Note Regarding Hypertrophy of Ligamenta Flava, J. A. M. A. **113**:2029-2034 (Dec. 2) 1939.

hospitalization entails in the majority of cases. Patients who have no bone removed can be allowed out of bed the day after operation, a distinct advantage particularly for elderly and obese patients.

In a small percentage of cases a fusion operation is indicated at the time of removal of the protruded disk. Preservation of all laminas and

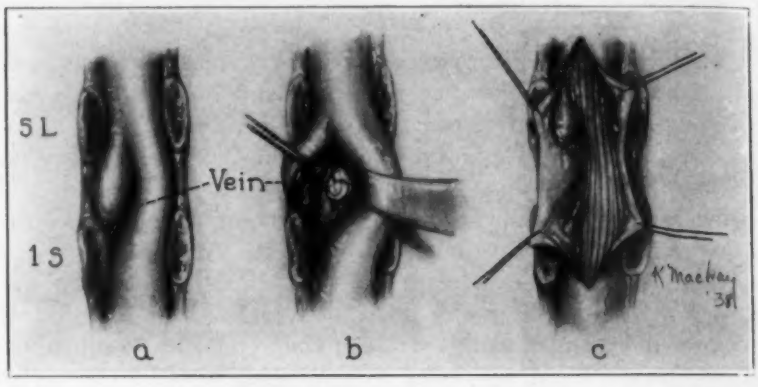

Fig. 6.—Drawing representing certain steps in the course of a classic laminectomy in which two spinous processes and two pairs of laminas have been sacrificed to expose a protruded intervertebral disk.

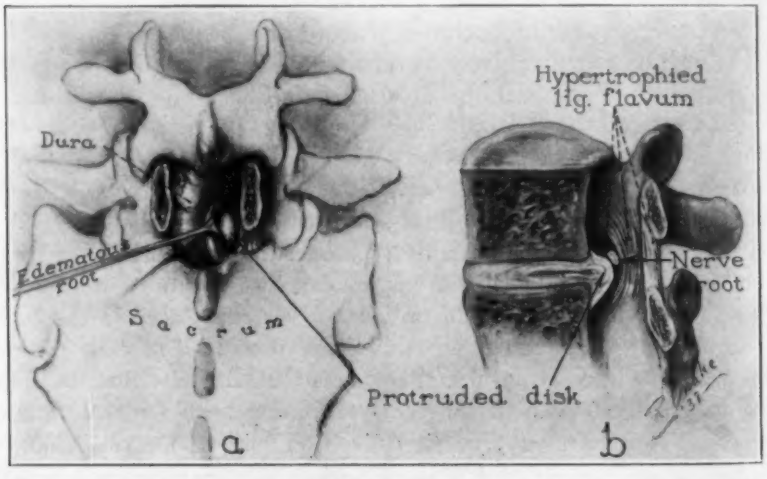

Fig. 7.—Drawing representing exposure of a protruded intervertebral disk by removal of one spinous process and one pair of laminas.

spinous processes gives the orthopedic surgeon a much better and broader field for anchoring of the bone graft. This is particularly desirable in cases of spondylolisthesis,[8] for which a double bone graft is advisable.

8. Meyerding, H. W.: Spondylolisthesis as an Etiologic Factor in Backache, J. A. M. A. **111**:1971-1976 (Nov. 26) 1938.

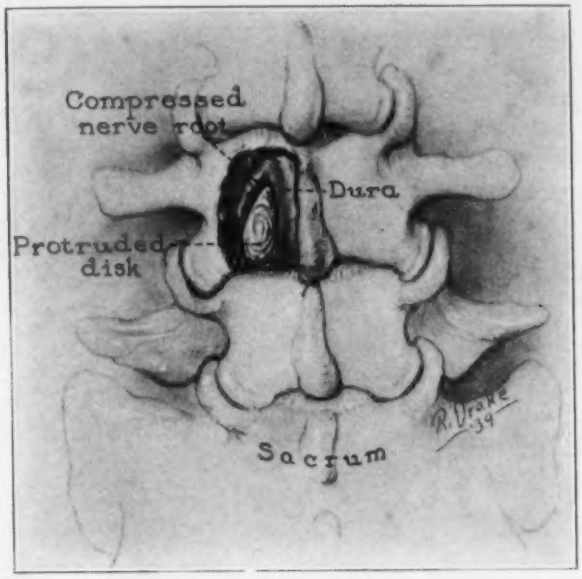

Fig. 8.—Drawing of a protruded intervertebral disk exposed by hemilaminectomy. The spinous process and the lamina of the opposite side are preserved.

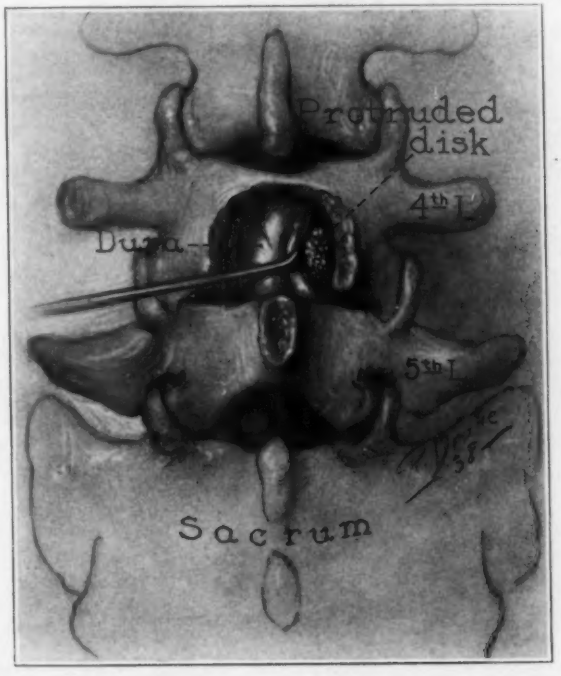

Fig. 9.—Drawing of a protruded intervertebral disk exposed by partial laminectomy, a procedure in which no neural arch is completely interrupted.

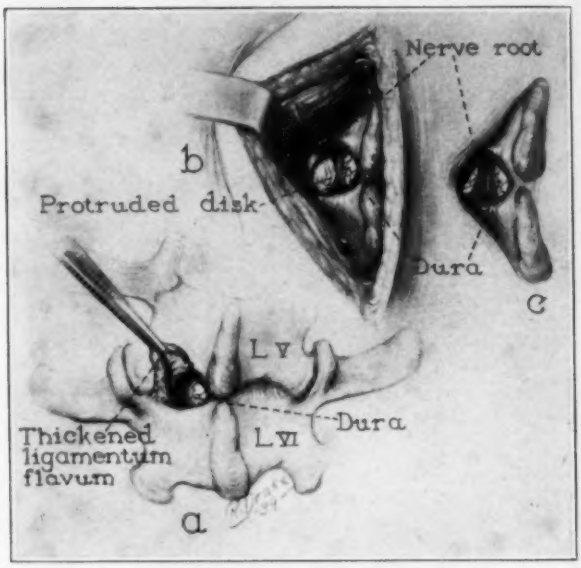

Fig. 10.—Drawing showing the removal of a protruded intervertebral disk without laminectomy and without removal of any bone: *a*, resection of the hypertrophied ligamentum flavum; *b*, exposure of the protruded portion of the disk, and *c*, restoration of the spinal canal to normal size and shape after the protruded part of the disk has been removed.

Fig. 11.—Anteroposterior roentgenogram showing evidence of a hemostatic silver clip in the center of the lumbosacral disk from which a protruded body was removed without removal of any bone.

RECURRENCE OF PROTRUDED INTERVERTEBRAL DISK

When a protruded intervertebral disk has been removed, does further fragmentation and protrusion of that disk occur? This question has been asked many times. When we first began to remove protruded intervertebral disks in large numbers we asked ourselves that same question. That further protrusion would occur, particularly if the patient subjected his back to unusual stress or strain, seemed likely since the entire disk is never removed. Only those parts of the disk that are fragmented and lying more or less free from the main bulk of the disk are removed at

Fig. 12.—Photograph of patient two weeks after operative removal of a protruded disk, to show the small incision which is required.

operation. Nature is kind to human beings, and she is most beneficent to those who wield the scalpel. If she were not, most operations on the colon would be fatal, patients having tonsillectomy would bleed to death, and all patients subjected to operative removal of intervertebral disks would return with recurrent symptoms. If nature is given a chance, she will heal over the raw surfaces left by the surgeon and the resultant healed wound often will be stronger than the original tissue, the continuity of which was severed by the surgeon.

To be sure, the surgeon should do his utmost to leave nature unhandicapped in her endeavor, and he should warn his patients of the pitfalls into which they may stumble. The patient who has had a protruded disk

removed should be specifically instructed as to what he must not do until sufficient time has elapsed for firm healing to have taken place. It is our practice at the time of dismissal of such patients to advise them to do no lifting or straining for a period of three months from the date of dismissal. They are advised not to carry their luggage, move furniture about the house or lift children or any object likely to put stress on the back. They are told not to dance or play golf. Clerks and those employed in sedentary occupations are advised not to return to work for three months. It has been found that even a swivel chair becomes uncomfortable when occupied for six to eight hours by a patient recently operated on. If the patient returns to work too soon, he is likely to have vague aches and pains, and soon he indulges in self pity, which is accentuated by overzealous friends and anxious relatives. In time he may even assume that he has obtained no relief from his operation and that his condition is just as poor as, or even worse than, it was before the operation.

It is particularly important to warn day laborers, truck drivers and others who are accustomed to hard manual work to return to their former duties gradually. Such persons must regain confidence in their ability to carry on. This is especially true if compensation or insurance is involved. If the patient has gone for a long time without the true nature of his disability being recognized, and if he has been considered by some to have a post-traumatic neurosis or even to be a malingerer, he should be given special consideration and reassurance until he has been reeducated and shown that he can carry on in a normal way.

In spite of our best efforts and the giving of sound advice based on our knowledge of anatomy, physiology, pathology and psychology and our considered clinical judgment, some patients will claim that they have not been benefited by treatment. Others will state that they were better or even completely relieved for a time but that, without any violation of professional advice, the symptoms returned. A few will return years afterward and relate a history of having been completely free of pain following operation until on a particular day when unusual stress or strain was applied to the back. For instance, this incident might have been followed by backache which rapidly developed into all the symptoms for relief of which the original operation had been performed, or at the time of straining of the back all symptoms might promptly have returned. Of course, there is no reason why another intervertebral disk could not protrude, and this is particularly true in the light of our relatively high incidence (approximately 10 per cent) of multiple protrusions found at the time of the original operation. However, our experience leads us to conclude that if there is a recurrence of symptoms due to a protruded

intervertebral disk, it is most likely due to further protrusion at the site of the original protrusion. In more than 500 operations for protruded intervertebral disks, we have encountered only 5 recurrences, in all 5 of which the disk which was the site of a protrusion at the time of the original operation was again involved.

The first case of recurrence was reported in the *Proceedings of the Staff Meetings of the Mayo Clinic*.[9] Relief was obtained following the removal of a large protruded portion of the fourth lumbar disk. However, two months after the patient's return home he began to have a recurrence of his old symptoms, following a head cold. Whether or not he had bronchitis and cough is not known. Shortly thereafter, the sciatic pain became markedly exaggerated while he was carrying some pails of water. He was operated on a second time seven months after the original laminectomy, and a large amount of protruded fibrocartilage which came from the fourth lumbar disk was removed, with relief of his symptoms. After that experience, more care was taken in searching for additional fragments of the disk, particularly fragments still remaining within the center of the disk. It seemed desirable not to curet the disk and cartilaginous plates attached to the vertebral bodies or to use a strong bone-cutting instrument within the disk. In looking around for a suitable instrument to pick up fragments from the space between the vertebral bodies, one of us (Love) discovered that the rhinologist's nasal punch was admirably suited for this work (fig. 5*h*). Often, after all fragments seem to be removed, this instrument will enable the operator to bring out one or more additional free fragments from within the disk. Naturally, if these fragments are not removed, a recurrence can be expected.

The second case of recurrence was that of a man who had had a protruded fragment of the fourth lumbar disk removed Feb. 7, 1938; it had caused intractable left sciatic pain, which had confined him to bed and had resulted in great loss of weight. Removal of the protruded portion had afforded immediate and complete relief. In May 1939, while fishing, he turned around in a boat to pick up a minnow bucket and was suddenly seized with pain low in the back and along the distribution of the left sciatic nerve. The pain was so severe that he was returned to our care on a stretcher. Roentgenoscopic examination of the spinal canal after injection of radiopaque oil revealed evidence of partial obstruction; the shadows were not characteristic of any particular lesion; that is, it could not be stated whether stoppage of the oil was the result of adhesions at the site of the old laminectomy or of a space-occupying lesion such as protrusion of the disk. In view of the nature of the symptoms and the characteristic root type of pain, operation was advised. On Aug. 17, 1939, a large protruded fragment of the fourth lumbar disk was removed, with complete relief of symptoms.

The third case of recurrence was that of a man 47 years of age. He first registered at the clinic on March 24, 1937, when he was 45 years of age. At that time he complained of intermittent backache and left sciatic pain of five years' duration. The patient's symptoms had started in the winter of 1931-1932, when he had first noted left sciatic pain which could not be attributed to any specific cause. In January 1937 the pain became more severe, and from then on

9. Love, J. G.: Recurrent Protrusion of an Intervertebral Disk, Proc. Staff Meet., Mayo Clin. **13**:404-408 (June 29) 1938.

he was unable to work until after treatment at the clinic. Usually there was considerable aggravation of the pain around 4 a. m. The backache was aggravated by standing up and by riding in a car.

Examination showed a listing of the patient toward the left, and all spinal motions were limited. There was tenderness over the lumbosacral area. The right leg was about 3 inches (7.5 cm.) shorter than the left, owing to an old fracture of the tibia. This was compensated for by use of a higher heel on the right shoe. Neurologic examination revealed that both achilles reflexes were normal. Examination of the spinal fluid revealed a total protein content of 50 mg. per hundred cubic centimeters.

A clinical diagnosis of protruded intervertebral disk was made, and a study was performed with radiopaque oil. Examination by Dr. Camp revealed a defect typical of protruded intervertebral disk at the fourth lumbar interspace. Laminectomy was performed, and a midline protrusion of the fourth lumbar disk was removed. The laminectomy consisted of removal of the spines and laminas of the third and fourth lumbar vertebrae and part of those of the fifth. Extradural exploration revealed no evidence of protruded intervertebral disk. The dura was incised, and much edema and matting together of the roots of the cauda equina over the fourth intervertebral space were detected. The roots were separated, and there was a classic midline protrusion of the fourth lumbar intervertebral disk. Incision of the dura mater permitted escape of a large fragment of cartilage, following which the canal was normal in size and shape. Because of slight oozing, a muscle pledget was placed in the dural incision for hemostatic purposes. The dura was closed with continuous sutures of silk. A piece of folded membrane was placed over the line of suture. The wound was closed in the usual manner, and one Penrose drain was used.

The patient was kept in bed for thirteen days following operation. His convalescence was uneventful, and at the time of dismissal he was completely relieved of pain. Postoperative neurologic examination gave negative results.

The patient returned Aug. 16, 1939. He stated that he had been well, had experienced no pain and had walked without aid and without abnormality, following his operation, until July 31. On that day he turned to his left and leaned over toward the floor to pick up a package. Before he could pick it up he was seized with a sudden severe pain which started in the left buttock and followed the distribution of the sciatic nerve downward to the heel. Since that time the pain had been severe and constant. At times the left leg became numb, but there had been no noticeable change in its strength. There were no symptoms referable to the right leg. He stated that whereas prior to his first operation the pain was more severe in the back than in the leg, since the recurrence of pain in July all the pain had been in the leg and there was no pain in the back. Conservative treatment had been tried at home without relief.

Examination by Dr. Ghormley revealed obliteration of the lumbar lordosis with a list to the right. All spinal motions were limited 50 per cent. Neurologic examination revealed slight diminution of the left achilles reflex. The Kernig and Lasègue signs were present. A diagnostic spinal puncture and a spinogram made at the same time on August 17 revealed no air below the fourth lumbar interspace. The total protein content was 45 mg. and there was 1 lymphocyte. It was advised that the old site of laminectomy be explored in association with Dr. Ghormley, who felt that in view of the recurrence of symptoms a bone graft should be performed.

On August 21 we opened the old wound, dissected the scar tissue away and palpating opposite the fourth interspace found a mass. At first we could not be certain whether this represented scarring or recurrent protrusion of the disk. When the nerve root was retracted, there was classic evidence of protrusion of the disk, and when the posterior longitudinal ligament, or whatever had developed to take its place, was incised, a huge fragment of cartilage was removed; this was one of the largest that we have ever seen. When this was removed, there was a large cavity between the vertebrae. After the disk had been removed, a graft, which had been taken from the left tibia and divided into two pieces, was placed by Dr. Ghormley from the third lumbar to the second sacral vertebra.

The fourth case of recurrence was that of a woman 39 years of age, who had right sciatic pain. On March 15, 1937, laminectomy was performed with removal of a protruded portion of the fourth lumbar disk by resection of the spines and laminas of the fourth and fifth lumbar vertebrae. The patient returned in June 1939 and stated that following the operation in 1937 she had not had further backache or sciatica until February 1939, when she began to have mild aching pain in the right buttock and lower lumbar region. Six weeks prior to this admission there was a sudden onset of pain low in the back with extension of the pain to the right thigh and external surface of the right leg. The pain was worse on coughing and sneezing, but there was no pain at night.

The results of examination were negative. The achilles reflexes were normal. There was no Kernig sign, and there was no sensory disturbance to be detected objectively; however, the patient complained of paresthesias over the lateral aspect of the right thigh and leg. The patient was seen in consultation by Dr. Meyerding, who advised that a corset be used for support and that physical therapy be employed over the lower part of the back. We told the patient and her husband that if the symptoms did not subside further surgical work would have to be considered. She returned after a thorough trial of physical therapy, which included hot baths, and stated that instead of her condition becoming improved, it had become worse.

On August 22 the old wound was opened, and underneath the nerve root on the right side was a classic example of recurrent protrusion of the fourth lumbar disk. One huge fragment and several smaller fragments were removed, after which there was no pressure on the cauda equina. Dr. Meyerding then proceeded with a bone graft. An osteoperiosteal graft 2 inches (5 cm.) long and 1 inch (2.5 cm.) wide, taken from the left tibia, was sutured over the exposed dura and the outer layer of the periosteum toward the dura mater, and multiple bone chips were placed along the course of the graft. A double bone graft taken from the left tibia was sutured so as to bridge the third, fourth and fifth lumbar vertebrae and upper two segments of the sacrum. Cancellous bone removed by use of a curet was packed around it. Arthrodesis of the facets of the third and fourth lumbar vertebrae was performed on both sides.

The fifth recurrent protrusion was encountered in a man 29 years of age. On June 17, 1937, transdural removal of a large portion of a lumbosacral disk which protruded in the midline was effected. Prior to this the patient had had backache and "sciatica" intermittently for eight years. After operation he was completely relieved until Sept. 19, 1939, when, after heavy lifting, he noted that a sudden sneeze gave rise to pain in the lower part of the back. The pain gradually became worse and within five days extended down along the course of the sciatic nerve. On October 4 another large protruded portion of the lumbosacral disk was removed extradurally, and then a graft was taken from the tibia and applied to the spine; it extended from the third lumbar to the second sacral spinous process. The latter procedure was performed by Dr. Ghormley.

If a recurrence is encountered, how should it be handled? Should it be treated as if it were the original lesion, or is there anything which one can do to prevent further recurrences? This cannot be answered dogmatically and without reservation. We believe that each case should be considered as an individual problem and that the final conclusion about the matter should be reached only after all factors have been considered, such as the presence or absence of congenital anomalies of the back, the extent of the original laminectomy, the degree of relief following the first operation, whether or not there was some residual static backache, the type of work to be done by the patient, his build, his age, his general condition and the cause of the recurrence, if any. Doubtless, in some of the cases in which a recurrence occurs fusion will be required; in others an excellent result will be obtained from removal of the protruded portion of the disk without fusion. We cannot, of course, be certain that a spinal bone graft or fusion will prevent further trouble. Certainly, if the patient has a weak back, internal fixation in the form of a bone graft is desirable.

Of the 5 cases of recurrent protrusion which we have encountered, in 3 fusion (a bone graft obtained from the tibia and applied to the back) was performed at the same time that the recurrent protruded body was removed. In the other 2 cases simple removal of the protruded fibrocartilage gave relief. It is too early yet to know the answer regarding recurrent protrusion, even in these 5 cases; for, at the time of this writing, 1 of the patients is still in the hospital.

RESULTS OF OPERATIVE REMOVAL OF PROTRUDED DISKS

In medicine and surgery it has become customary to report results as based on "five year cures," and we believe that this is a fine thing. It tends to avoid undue enthusiasm for any so-called new type of therapy. Since most of our patients have been operated on within the last five years, it is too early to know what the ultimate results will be. This is particularly true in evaluating results in groups of patients whose illness is characterized by remissions.

To date we are gratified with the results which we have obtained in this large group of 500 patients, most of whom had suffered for many years from intractable backache and sciatic pain. Craig and Walsh [10] in reporting on "the present status of the protruded disk syndrome" before the International Congress of Neurology held in Copenhagen, Denmark, in August 1939, made the following statement: "Following any operative procedure the amount of relief obtained depends upon certain factors, among which are the accuracy of diagnosis, the operative procedure, the postoperative care, the duration and severity of the pain,

10. Craig, W. McK., and Walsh, M. N.: Unpublished data.

the patient's susceptibility to pain, medicolegal questions, settlement of compensation and last, and very important, the patient's reaction to his disability."

When we come to analyze our data on the basis of five year cures, we shall find it, therefore, an extremely difficult problem; for today, unfortunately, the questions of liability, compensation and insurance loom large on the horizon and add complications compounded to an already knotty problem. There have been only two hospital deaths in our entire series of cases in which operation was performed. One death was reported in *The Journal of the American Medical Association*.[11] The subsequent death was due to bilateral suppurative parotitis, which became fulminating and extended to involve the mediastinum as mediastinitis. The patient's wound was already healed, and he had been relieved of the severe sciatic pain for which the operation was performed.

A short résumé of a case will serve to illustrate how disabling protrusion of a disk can be, what the usual symptoms and signs are and what can be expected after surgical removal of the protruded body.

A patient 17 years of age was well until two months prior to operation when, while swimming, she experienced pain low in the back. The next day she was unable to straighten up. Within a few days mild paresthesias occurred on walking. At times there was radiation of pain down the posterior aspect of both thighs to the knees and occasionally to the right ankle and instep. The pain was exaggerated by spinal motion, attempts at straightening the back, laughing and coughing. Pain at night occasionally disturbed her sleep. The patient's maternal aunt had had an operation in the thoracic region of the spine for "tumor," and a suboccipital craniotomy had been performed eight years previously, elsewhere, for syringomyelia. This aunt was becoming paralyzed in her feet and was staggering a great deal when she walked. Possibly this unfortunate experience of the aunt, together with the absence of definite objective evidence of involvement of the central nervous system, had led to a diagnosis elsewhere of hysteria in the case of the niece.

On examination at the clinic there was a marked list of the patient's body toward the left with increased prominence of the right hip and scoliosis (fig. 13). Percussion of the right sacroiliac region caused severe pain. All spinal motions were painful, and forward bending of the head on the chest caused pain in the back. Kernig's sign was present and the achilles reflex was absent on the right. Roentgenologic examination of the lumbar and sacral portions of the spine gave negative results. A diagnostic spinal puncture, made through the second lumbar interspace, revealed no evidence of subarachnoid block. However, there was a total protein content of 90 mg. per hundred cubic centimeters of spinal fluid, and the globulin test gave a positive result. At the time of diagnostic puncture, air was injected into the subarachnoid space in order to localize a suspected intraspinal lesion. The films revealed a defect in the column of air at the fourth lumbar interspace.

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11. Love, J. G., and Walsh, M. N.: Protruded Intervertebral Disks: Report of One Hundred Cases in Which Operation Was Performed, J. A. M. A. **111:** 396-400 (July 30) 1938.

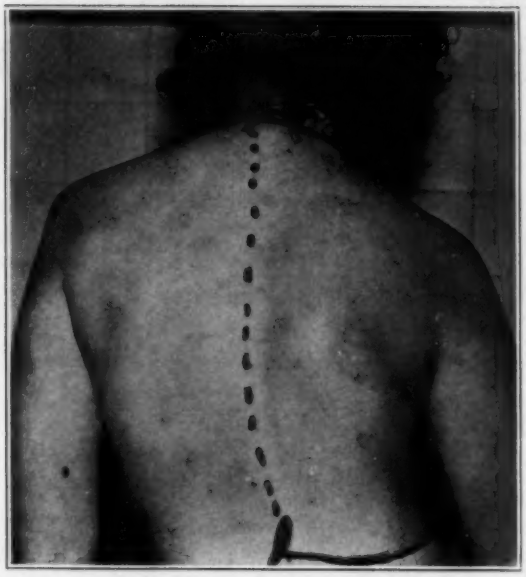

Fig. 13.—Preoperative photograph of patient; the severe listing of the body and the scoliosis secondary to protrusion of a lumbar intervertebral disk are evident.

Fig. 14.—Photograph of patient shown in figure 13, taken fifteen days after removal of a protruded portion of the fourth lumbar disk; the wound is well healed, and the scoliosis which had been present prior to operation has disappeared.

Partial laminectomy was performed, and after resection of an abnormally thick ligamentum flavum at the fourth interspace, a large protruded fragment of the fourth lumbar disk was removed extradurally. Part of the large fragmented cartilage was removed on the right side and part on the left. The ligamentum flavum at the fifth space was abnormally thickened also, and it was resected, but the lumbosacral disk was normal. The dura mater was not opened. The wound was closed in layers without drainage.

The patient received immediate relief from pain, and at the time of dismissal from our care, on October 27, fifteen days after removal of the protruded portion of the disk, her wound was well healed, her spine was straight and her condition was excellent (fig. 14).

PATHOLOGIC CHANGES OBSERVED IN THE HYPERTROPHIED LIGAMENTUM FLAVUM

Since a very definite change is almost constantly seen in the ligamentum flavum that overlies a protruded disk, it is necessary that some consideration be given to this structure whenever the subject of protruded disk is discussed. From the beginning of our work on disks, we have noted various abnormalities of the ligamentum flavum. The changes usually consist of marked thickening, increased firmness and decreased elasticity. On being cut, the ligaments impart an entirely different type of resistance from that encountered in the resection of normal ligamenta flava. Their cut surfaces appear whitish gray rather than yellow.

Dr. Dockerty, of our department of pathology, has interested himself in these structures and has favored us with the following preliminary report of his observations. What are the pathologic changes observed in cases of so-called hypertrophy of the ligamentum flavum? The present study is far from complete as regards both surgical material and normal controls selected from the various age groups. On the other hand, certain definite changes seem to occur so consistently that we feel justified in recording them in this preliminary report.

Grossly, the affected ligaments are thicker than normal; they measure 4 to 6 mm. in cross section as against an established normal of from 2 to 5 mm. The cut surface, instead of being homogeneously yellow, reveals, in a typical case, white bands running throughout. Microscopically, the changes, seen best with special stains for elastic tissue, are as follows:

1. Fragmentation, usually longitudinal, of the elastic tissue fibrils. The ends of these frayed fibrils often appear shriveled.

2. Replacement of damaged fibrils by a more primitive type of mesoderm, namely, fibrous connective tissue. In many instances the latter is present in the form of wide bands that run throughout the length of the affected ligament.

3. Blood vessels are few, and those present are small in caliber as a result of the hyaline substance which is deposited within their walls and which replaces the muscularis. This finding leads one to wonder whether vascular damage as a result of trauma may not explain the other changes observed. In three "normal" controls studied to date, vascular changes were not noted, and the ligaments had none of the alterations noted microscopically.

XANTHOMA OF TENDON SHEATHS AND SYNOVIAL MEMBRANES

A CLINICAL AND PATHOLOGIC STUDY

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This paper is a review of the literature dealing with xanthoma and of the cases observed at the Mayo Clinic and an attempt to arrive at certain definite conclusions by which this lesion can be properly classified. Owing to the histologic similarity of the synovial membrane of the tendon sheaths and that of the joints,[1] it was felt that growths involving both these structures should be considered. Other types of solitary xanthoma occur in bone and in subcutaneous tissue, but they will not be discussed in this paper. An effort has also been made to refrain from any reference to the general subject of the xanthomatous diseases except when it is necessary as an aid in establishment of the true nature of these solitary tumors.

HISTORICAL REVIEW

The first reference in the literature to the group of conditions now listed under the general heading of xanthoma was by the French dermatologist, Rayer.[2] In 1836 he described under the name *plaques*

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Thesis submitted by Dr. Galloway to the Faculty of the Graduate School of the University of Minnesota in partial fulfilment of the requirements for the degree of Master of Science in Orthopedic Surgery.

1. Piersol, G. A.: Normal Histology, with Special Reference to the Structure of the Human Body, ed. 15, edited by W. H. F. Addison, Philadelphia, J. B. Lippincot Company, 1932, pp. 63 and 75-76. Bremer, J. L.: A Text-Book of Histology Arranged upon an Embryological Basis, ed. 5, Philadelphia, P. Blakiston's Son & Co., 1936, pp. 90-91 and 120.

2. Cited by Rowland, R. S.: Xanthomatosis and the Reticulo-Endothelial System: Correlation of an Unidentified Group of Cases Described as Defects in Membranous Bones, Exophthalmos and Diabetes Insipidus (Christian's Syndrome), Arch. Int. Med. **42**:611-674 (Nov.) 1928; cited by Gruenfeld, G., and Seelig, M. G.: The Nature of So-Called Xanthoma: A Critical Review, Arch. Path. **17**:546-573 (April) 1934.

jaunatres des paupières those yellowish eruptions usually located on the eyelids but occasionally found in other parts of the skin and at present commonly spoken of as xanthoma palpebrarum or xanthelasma, the latter being a term proposed by Wilson [3] in 1863, meaning yellow plaques.

Lebert,[4] in 1845, first introduced the term xanthoma and attributed the color of the tumor to a peculiar sort of fat, to which he gave the name xanthos. He was followed in 1869 by Smith,[5] who again suggested the name xanthoma and spoke of the tumor-like appearance of the yellow nodules. Lebert [4] recognized these tumors as benign and differentiated them from similar fibrous tumors, especially from sarcomas. In 1851, Addison and Gull [5] described 4 cases of xanthoma associated with hepatic disease and jaundice, a condition at present designated by the term xanthoma multiplex, and 1 case of xanthoma associated with pancreatic disease, now known as xanthoma diabeticorum. They mentioned involvement of the tendon sheaths of the fingers in 1 of their cases. Involvement of the tendon sheaths was cited also by Fox [6] and by Carry [6] in 1897; this was referred to by Fox as the "gout form" of xanthoma.

Tendon Sheaths.—1852 to 1890: According to Gruenfeld and Seelig,[7] Beekman,[8] King [9] and Ragins,[10] the first description of solitary xanthoma of the tendon sheaths was published in 1852 by Chaissaignac,[11] who described a nodular lesion on the index and middle fingers of the right hand, and the second was given in 1857 by Spencer Wells,[12]

3. Cited by Rowland, R. S.: Xanthomatosis and the Reticulo-Endothelial System: Correlation of an Unidentified Group of Cases Described as Defects in Membranous Bones, Exophthalmos and Diabetes Insipidus (Christian's Syndrome), Arch. Int. Med. **42**:611-674 (Nov.) 1928.

4. Cited by Garrett, C. A.: Tumors of the Xanthoma Type, Arch. Surg. **8**: 890-907 (May) 1924.

5. Addison, T., and Gull, W.: On a Certain Affection of the Skin, Vitiligoidea —a. Plana, Tuberosa, with Remarks and Plates, Guy's Hosp. Rep. **7**:265-276, 1851.

6. Cited by Thannhauser, S. J., and Magendantz, H.: The Different Clinical Groups of Xanthomatous Diseases: A Clinical Physiological Study of 22 Cases, Ann. Int. Med. **11**:1662-1746 (March) 1938.

7. Gruenfeld, G., and Seelig, M. G.: The Nature of So-Called Xanthoma: A Critical Review, Arch. Path. **17**:546-573 (April) 1934.

8. Beekman, F.: Giant-Cell Tumors of the Tendon Sheaths, Ann. Surg. **62**:738-745 (Dec.) 1915.

9. King, E. S. J.: Concerning the Pathology of Tumours of Tendon-Sheaths, Brit. J. Surg. **18**:594-617 (April) 1931.

10. Ragins, A. B.: Benign Tumors of the Tendon Sheaths of Unusual Size, Ann. Surg. **93**:683-690 (March) 1931.

11. Cited by Tourneux.[13]

12. Cited by Tourneux [13] and by King.[9]

who described a similar tumor of the index finger. Tourneux,[13] in 1913, after a review of all the previously reported cases in the literature, classified the growths as fusocellular sarcomas. Since opinion is divided as to their true nature, they have been classified and listed in this paper as probable and not true xanthomas of the tendon sheaths.

It was noted by Paget[4] in 1853 that the yellow tumors may be found in such places as the subcutaneous tissues, the eyelids, the conjunctiva, the cerebral membranes, the breasts and the uterus but that they are especially connected with bone. In addition, Paget sketched the pathologic picture of these tumors, describing large oval pigmented cells, irregular fragments of cells without a definite cell wall but with many nuclei, typical giant cells and spindle cells. He failed, however, to describe foam cells as such.

As was mentioned by Heurtaux[14] in 1891 and again by Tourneux[13] in 1913, the first authentic report of yellow giant cell tumor of the tendon sheaths must be accredited to Broca,[15] who, in 1860, described a case in which the tumor involved a tendon sheath of the right hand in a woman 20 years of age; to this type of tumor Broca[15] applied the name *myelome*. His report was followed by the description by Czerny,[15] in 1868, of a similar lesion, located on the right ring finger of a woman 20 years of age and diagnosed by him as *sarcome à myeloplaxes*.

Billroth[11] is reputed to have reported an example of this type of tumor in 1868. It was found, however, that he had recorded 3, 1 in which death due to generalized metastasis occurred within about a year, 1 in which the tumor recurred with axillary metastasis and 1 in which the growth involved the flexor tendon sheath of the forearm and death from pyemia followed amputation of the forearm. The first case is, of course, excluded from any consideration here, for it is evident that the tumor was malignant, and it had been listed by Tourneux[13] as a myxofibrosarcoma. Although in the second case the patient recovered after a second local excision of the growth and excision of the axillary lymph nodes, the inference that the tumor had metastasized must exclude it from this discussion. The lesion in the third case may possibly have been a xanthoma, but all indications would lead one to believe that amputation had been done for a malignant tumor, and, since a reasonable doubt exists, it has been discarded.

The next reports, therefore, of this type of tumor were those of Paquet[15] and Gross,[15] each of whom described 1 case in the year

13. Tourneux, J. P.: Les sarcomes des gaines tendineuses, Rev. de chir., Paris **47**:817-854, 1913.

14. Heurtaux, M. A.: Myélome des gaines tendineuses, Arch. gén. de méd. **167**: 40-54 (Jan.) 1891.

15. Cited by Tourneux[13] and by Heurtaux.[14]

1878. The growths were associated with the left palm and the right index finger respectively and were designated as *sarcome à myeloplaxes.* To these must be added 2 cases reported by Koenig [16] in 1881, 1 reported by Ferré [11] in 1888 and a similar case reported by Labougle and Cassaet [11] in 1890. All of these authors referred to the tumors as belonging to the order of giant cell sarcomas. This makes a total of 8 undoubted tumors of this type reported during the first thirty-one years of the history of the tumor.

During the same period several cases of probable xanthoma were discovered. One was reported by Eichhorst [11] in 1876. The patient was a girl 15 years of age whose right leg had been amputated owing to a fusocellular sarcoma of the tendon sheath of the anterior tibial muscle that had been present for three years. One was reported by Markoe [11] in 1884, in which the tumor had recurred after local excision from the tendon sheath of the left great toe; 1 was described by Blum [11] during the same year, in which the growth had been present for fourteen years in the flexor tendon sheaths of the sole of the right foot and recovery took place after amputation of the leg; 1 was reported by Reverdin [11] in 1885, in which the tumor had been present for ten years and the patient recovered after amputation of the thumb, and by Dumrath [11] in 1886, in which the growth had persisted for seven years and the patient recovered after local excision. In addition 2 cases were reported by Mayer [11] in 1886, the tumors being diagnosed as sarcoma, in which recovery occurred after conservative surgical intervention. These cases, together with those reported by Chaissaignac [11] and Spencer Wells [12] and the cases of true xanthomas, make a total of 18 cases reported to the end of 1890.

1891 to 1899: Heurtaux,[14] in 1891, was the first to make a critical study of this subject. He differentiated this group of tumors from the sarcomas and gave them the name of myeloma, after Nélation,[17] who had previously suggested the name myeloma or medulloma for similar osseous structures observed by him and believed by him to be connected with the skeletal system only. Heurtaux [14] stated that the term myeloma should not be used as a synonym for sarcoma. He recorded 3 personally observed cases in which the lesions were located in the tendon sheaths of the fingers and a fourth case, in which the findings were suggestive but no operation was done.

Dor,[16] in 1898, in his description of a lesion of the right index finger, was the first to describe the xanthoma cell and perhaps the first to con-

16. Cited by Bellamy, H. F.: The Myeloid Tumor of Tendon Sheaths, J. Path. & Bact. **7**:465-480, 1901.

17. Cited by Heurtaux [14] and by Bellamy, H. F.: The Myeloid Tumor of Tendon Sheaths, J. Path. & Bact. **7**:465-480, 1901.

clude that these tumors are of inflammatory origin. He also stated the opinion that they are of a mixed type, composed of both myeloid and xanthomatous tissue but having a common cellular origin. As a result of his observations he proposed the term myeloxanthoma.

From 1891 to 1899 inclusive, 13 more cases were described in the literature, in 9 of which the tumors were located on the hands or fingers and in 4 of which they occurred about the ankle or on the toes. One case was reported by each of the following: Pilliet [11] (1893), Pilliet and Mauclaire [11] (1894), Longuet and Landel [11] (1895), Bonhomme [18] (1897), Bonjour [18] (1897), Venot [11] (1898), Menciére [11] (1898), Albertin and Paviot [11] (1899) and Arcoleo [11] (1899). Two each were reported by Malherbe [11] (1896) and Targett [19] (1897). All except Targett classified the tumors as *sarcome à myeloplaxes*. Targett,[19] on the other hand, said they had the character of dense fibrosarcoma containing within its stroma large numbers of foreign body giant cells, the presence of which he failed to explain. He reported the growths as malignant spindle cell sarcomas and suggested that they might have originated from some bone-forming membrane. Bonjour [18] concluded that the myeloid tumors form a distinct group of neoplasms with a mother cell probably originating in the medullary tissue of bones. He divided them into three groups: (1) myeloma of the genus epulis, (2) myeloma of tendon sheaths and fibrous tissue and (3) central myeloma of bone. Bonhomme [18] concluded that the tumor in his case was a nonmalignant neoplasm resulting from chronic inflammation of the tendon sheath, possibly due to trauma. These 13 cases added to those already reported make a total of 25 cases of proved xanthoma of the tendon sheaths reported by the turn of the century.

1900 to 1909: The twentieth century opened with the report of 5 cases by Müller,[11] in all of which there was involvement of the hand and finger tendon sheaths, and a sixth, by the same author, in which successful excision was done. The tumors in the first 5 cases he diagnosed as giant cell sarcomas and that in the sixth as a melanotic sarcoma (in this paper it has been listed with the probable xanthomas). During the same year, Delbance [20] reported a case in which a nodular lesion involved the extensor tendon sheath of the thumb in a man aged 31.

The year 1901 revealed several cases: 1 reported by Tomaselli,[11] of a tumor which he called a giant cell sarcoma; 4 reported by Heller,[11]

18. Cited by Bellamy, H. F.: The Myeloid Tumor of Tendon Sheaths, J. Path. & Bact. **7**:465-480, 1901, and by Tourneux.[18]

19. Targett, J. H.: Giant-Celled Tumours of the Integuments, Tr. Path. Soc. London **48**:230-235, 1897.

20. Cited by Mason, M. L., and Woolston, W. H.: Isolated Giant Cell Xanthomatic Tumors of the Fingers and Hand, Arch. Surg. **15**:499-529 (Oct.) 1927.

and 5 reported by Bellamy.[21] The tumor in Tomaselli's case was located on a foot; all those in Heller's cases involved the tendon sheaths of fingers, and all his patients recovered after local excision. Heller's diagnosis was *sarcome à myeloplaxes*. In 4 of Bellamy's cases the growth was connected with the fingers, and in the fifth it involved the palm. Bellamy listed as important characteristics of these tumors the presence of adult connective tissue, certain proliferating cells, multinucleated or giant cells, blood vessels with actively proliferating endothelium and, finally, advanced stages of fatty degeneration. As a result of this study he concluded that, although these tumors contain large numbers of giant cells, they do not belong among the giant cell tumors but that, owing to the fact that their evolution is due to proliferation of the endothelial cells of the blood vessels, they should be called endotheliomas. However, since large numbers of giant cells also play a prominent part in the pathologic picture of these growths, he concluded that they should be termed myeloid endotheliomas.

In 1902, Martini [11] described a giant cell sarcoma which was successfully excised after the second attempt. Turner,[22] during the same year, described a myeloma of the tendon sheath of a finger in a young woman resulting from overstrain due to excessive violin practice. The following year, Bloodgood [23] added 2 cases under the classification of hemangiomatous elephantiasis. He later [24] regarded the growths in these 2 cases as similar to those under discussion in this paper. He added that when these tumors are adherent to or associated with tendon sheaths even above the fingers and toes (on the hand, wrist, foot or ankle) and have the mottled appearance of xanthoma, they can almost always be differentiated from the sarcomas. The presence of foam cells, according to him, rules out the diagnosis of sarcoma, as does usually the presence of the foreign body giant cell.

Coenen,[11] in 1904, employing the term "giant-cell sarcoma of the tendon sheaths," added 6 cases. In 5 the tumors were allied with the flexor, and in 1 with the extensor, tendon sheaths of the fingers.

In 1905, Malapert and Morichau-Beauchant [25] described a giant cell sarcoma of the flexor tendon sheath of the right middle finger

21. Bellamy, H. F.: The Myeloid Tumor of Tendon Sheaths, J. Path. & Bact. **7**:465-480, 1901.

22. Turner, G. R.: A Case of Primary Sarcoma of the Synovial Membrane of the Ankle-Joint, Tr. Clin. Soc. London **35**:137-138, 1902.

23. Bloodgood, J. C.: Haemangiomatous Elephantiasis, Progrès méd. **4**:154-157 (Dec.) 1903.

24. Bloodgood, J. C.: Xanthomas, Arch. Surg. **8**:882-889 (May) 1924.

25. Malapert, P., and Morichau-Beauchant, R.: Sarcome à myéloplaxes de la gaine synoviale du fléchisseur du médius, Bull. et mém. Soc. anat. de Paris **80**:390 (May) 1905.

which presented no evidence of recurrence after amputation of the finger. In the same year, Suter [26] recorded a digital tumor for which amputation of the distal phalanx was done owing to erosion by the tumor of a portion of that phalanx.

Gaudiani,[11] in 1906, described 2 tumors. One of them was found by Tourneux [13] to be a melanotic giant cell sarcoma. It was located on the flexor tendon sheath of the right ring finger, had been present for twelve years and showed no recurrence after local excision; it is, therefore, classified in the present paper with the probable xanthomas. The other was diagnosed by Gaudiani [11] as a giant cell sarcoma of the extensor tendon sheath of the left great toe and was successfully excised from a girl 12 years of age. Bazy,[11] in 1907, followed with another, and in 1908 Fritsch [11] added 2 more, all of which received the name of giant cell sarcoma, or *sarcoma à myeloplaxes.*

Seven cases were reported by Lenzi and Abetti [11] in 1909. The tumors in 6 involved the flexor tendon sheaths of the fingers and that in 1 the extensor tendon sheath of a foot. The growths were classified as giant cell sarcomas. In the same year Kammer [27] cited 2 cases. In 1 the tumor was situated on a finger, and in the other, on a toe.

During this period (1900 to 1909) 41 cases of undoubted xanthoma of the tendon sheaths were reported, bringing the total up to 66. However, there is 1 case of probable xanthoma that might be added; it was reported by Nony [11] in 1909. The tumor was successfully excised from the flexor tendon sheath of the left forearm and was diagnosed as a globocellular sarcoma.

1910 to 1919: Under the term myeloma, Mathews,[28] in 1911, reported a case of tumor of the flexor tendon sheath of the index finger, and during the same year Russell [29] added another.

In 1912, Hedinger [30] reported 4 cases but gave no details concerning them except the age and sex of the patients. The following year, Spiess [31] added 4 cases and suggested the name *Hämosiderin Sarcoma*

26. Suter, F. A.: Zur Casuistik der Fingertumoren, Arch. f. klin. Chir. **75**:624-628, 1905.

27. Cited by Smith, C.: The Histology and Nature of So-Called Foam-Cell Tumors with a Report of Four Cases of Endothelioma Xanthomatosum, Surg., Gynec. & Obst. **14**:551-557 (May) 1912.

28. Mathews, F. S.: Myeloma of the Tendon Sheath, Ann. Surg. **53**:847-848 (June) 1911.

29. Russell, J. I.: Sarcoma of the Tendon Sheath of the Flexor Longus Pollicis Muscle, Ann. Surg. **53**:285-286 (Feb.) 1911.

30. Hedinger: Zur Frage der sogenannten Myelome der Sehnenscheiden, Centralbl. f. allg. Path. u. path. Anat. **23**:904 (Oct. 31) 1912.

31. Spiess, P.: Zur Lehre der von Sehnenscheiden und Aponeurosen ausgehenden Riesenzellensarkome, Frankfurt. Ztschr. f. Path. **13**:1-44, 1913.

gigantocellulare xanthomatodes der Sehnenscheiden und Aponeurosen. He added that pathologically a chronic granulation process can be safely excluded, that the tumors are definitely benign and that they resemble epulis to a considerable extent.

The term granuloma made its appearance in 1913, when Fleissig [32] described 3 growths located on the fingers. He pointed out that these tumors lack the principal diagnostic points of neoplasms, such as polymorphism, polychromatophilia, destructive invasion of the surrounding tissues and mitosis, and asserted that they are benign. The same year, Le Filliatre [33] added 1 more case to the increasing list.

Grant and Stewart,[34] in 1914, described a nodular lesion that had recurred after local excision in the tendon sheath of a finger. They regarded it as a myeloid endothelioma and emphasized the important role that trauma plays in the causation of this variety of tumor. Using the name "pigmented giant-cell xanthosarcoma," Landois and Reid,[35] in this same year, reported 4 personally observed cases and a fifth observed by Robinson, of Clifton Springs, New York. Two of their cases had already been reported by Bloodgood [28] in 1903, which leaves only 3 new cases to their credit.

In 1915, Stewart and Flint [36] described 2 tumors, 1 on the flexor surface of the right thumb and the other on the flexor surface of the left wrist. During that year, Beekman added 3, 2 located on fingers and 1 on a great toe. He also reviewed the literature and, after a consideration of the preexisting data, concluded that it had not been definitely proved that these tumors are caused by inflammation or chronic irritation. He stated, however, that they certainly do not belong under the classification of sarcoma. He stated that histologically they resemble giant cell epulis more than any other type of giant cell tumor (although they do not arise from the periosteum as does epulis) and that they further resemble epulis in that they do not recur after complete removal and never metastasize. He then suggested the name "giant-cell sarcoid tumors of the tendon sheaths." He agreed with Bloodgood [23] that the term giant-cell tumor is well established and should not be dropped.

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32. Fleissig, J.: Ueber die bisher als Riesenzellensarcome (Myelome) bezeichneten Granulationsgeschwülste der Sehnenscheiden, Deutsche Ztschr. f. Chir. **122**: 239-265, 1913.

33. Le Filliatre: Sarcome à myéloplaxes de la gaine du jambier postérieur, Bull. et mem. Soc. anat. de Paris **88**:222-224, 1913.

34. Grant, T. P., and Stewart, M. J.: On Myeloid Tumors of Tendon Sheaths, with Report of a Case, Glasgow M. J. **81**:333-339, 1914; abstracted, Internat. Abstr. Surg. **19**:225 (Sept.) 1914.

35. Landois, F., and Reid, M.: Das pigmentierte riesenzellenhaltige Xantho-Sarkom der Extremitäten, Beitr. z. klin. Chir. **95**:56-73 (Dec.) 1914.

36. Stewart, M. J., and Flint, E. R.: Observations on the Myeloid Tumor of Tendon Sheaths, Brit. J. Surg. **3**:90-99, 1915-1916.

In 1917, Pybus [37] reported a nonrecurring myeloid tumor of the flexor tendon sheath of the right little finger.

One of us (Broders),[38] in his paper published in 1919, described 17 tumors, 1 of which was located in the subcutaneous tissue on the anterior surface of the leg, midway between the knee and the ankle, and was not related to any tendon sheath. This tumor will not be considered with the remaining 16, 10 of which were situated on the upper extremity and 6 on the lower. He described the macroscopic and microscopic appearance of the growths and suggested that the purpose of the foreign body giant cell is to absorb foreign material; in other words, it is a "clean-up cell." He spoke also of its morphologic similarity to the osteoclast and expressed the opinion that its function may be the same. In addition, he brought out the resemblance of these giant cells to those found in the medullary giant cell tumor of bones and gums, to those that collect around cholesterol crystals, blood pigment, nonabsorbable suture material and colloid and cornified epithelium in cases of epithelioma and to those associated with syphilis, leprosy, blastomycosis, coccidioidal granuloma and tuberculosis.

The decade from 1910 to 1919 revealed that 40 more undoubted xanthomas of the tendon sheaths had been recorded, making the total to the end of the decade 106. Two probable xanthomas were also seen; 1, reported by Gignoux [11] in 1911, was situated on a flexor tendon sheath near the malleolar region of the right foot and had been present for seven years. Recovery took place after amputation of the leg. The other was described by Jourdan and Étienne [11] in 1911. It was located in the tarsal region and had likewise been present for seven years. Both of these growths were diagnosed as globocellular sarcomas.

1920 to 1929: Krogius,[39] in 1922, suggested the name "xanthosarcoma" and described 4 cases; in 2 the lesion was on the lower extremity and in 2 it occurred on the upper. He expressed the opinion that, although growths located on the fingers are benign, those on the hands, forearms and feet are apt sooner or later to reveal a more malignant nature. During the same year, Kaufmann [20] reported 3 cases and Seyler [40] described 10, using the name of "xanthomatous granuloma." Of the tumors described by Seyler only 1 involved a tendon sheath. One was in a joint, and the remainder were subcutaneous,

37. Pybus, F. C.: A Note on a Case of Myeloma of the Tendon Sheath, Brit. J. Surg. **5**:172-173, 1917.

38. Broders, A. C.: Benign Xanthic Extraperiosteal Tumor of the Extremities Containing Foreign Body Giant Cells, Ann. Surg. **70**:574-581 (Nov.) 1919.

39. Krogius, A.: So-Called Xanthosarcoma of Tendon Sheaths, Finska läk.-sällsk. handl. **44**:102, 1922; abstracted, Internat. Abstr. Surg. **35**:415-416 (Dec.) 1922.

40. Seyler: Ueber xanthomatische Granulome, Virchows Arch. f. path. Anat. **239**:20-31, 1922.

1 located over the bridge of the nose, 1 about the temporal region, 1 on an ulnar nerve, 3 on the leg and 2 on the arm.

In 1923, Hartert [41] described 5 tumors which he called xanthosarcomas. Three were located on the feet and legs and 2 on the tendon sheaths of the fingers. About the same time, Buxton [42] reported a case which he had personally observed and 1 which he had collected from the Royal College of Surgeons. Buxton called both tumors "giant-cell myelomas" but distinguished them from sarcomas. He quoted Shattock as saying that these myelomas of tendon sheaths are the same as those found at the ends of the long bones. Shattock had suggested also that they are due to embryonic displacement of osseous elements into the tendon sheath, which is continuous with the bone, and that these displaced elements are related to the bone marrow.

Garrett,[43] in 1924, under the subtitle "fibrohemangioma," described 19 of the 76 recorded as xanthomatous. All of these 19 tumors contained foreign body giant cells, and 9 revealed the presence of foam cells. Two of the cases had already been reported by Bloodgood [23] in 1903. Garrett [43] did not specify the exact location of the tumors in the remaining 17 and as many or all of them may not have been associated with tendon sheaths, they were not included in the present paper. Using the subtitle "fibroma of tendon sheaths," Garrett also concluded that 13 of the total number of 30 were xanthomas. Of the remaining 17 in this group, all are reported as containing foreign body giant cells and pigment, and the similarity, in some respects, to the 13 considered to be xanthomas is noted. The differences between these two groups appear so slight that it is inconceivable that two distinct divisions could be made of them, and therefore they are all included in the present paper under the classification "xanthoma of tendon sheaths." Under the subtitle "granulation-tissue tumors," 1 lesion of the recorded 26 is considered to be xanthomatous in structure, and it contained foreign body giant cells, foam cells and pigment, but here again Garrett failed to locate the tumor, and since the location is not known the case is also excluded from the present paper. In addition, Garrett concurred in Bellamy's [21] opinion that tumors of this type are endotheliomas and stated that they are benign.

Dyke,[44] in 1924, reported 2 cases of tumor diagnosed as myeloma. He expressed the idea that the presence of giant cells is to be considered

41. Cited by Janik, A.: Tumors of Tendon Sheaths, Ann. Surg. **85**:897-911 (June) 1927.

42. Buxton, St. J. D.: Tumours of Tendon and Tendon Sheaths, Brit. J. Surg. **10**:469-474 (April) 1923.

43. Garrett, C. A.: Tumors of the Xanthoma Type, Arch. Surg. **8**:890-907 (May) 1924.

44. Dyke, S. C.: On the Significance of Anisotropic Fatty Substances in Myelomatous Tumours, J. Path. & Bact. **27**:5-10, 1924.

as evidence of the endothelial nature of these myelomatous tumors and, similarly, that the presence of foam cells containing droplets of anisotropic fat substance, probably cholesterol ester, is still further evidence of their endothelial origin. Weber,[45] in the same year, presented a case of xanthomyeloma of the tendon sheath and expressed the opinion that these tumors are associated with constitutional hypercholesteremia. Miller [46] called the lesion that he reported in the same year a xanthoma of the tendon sheath. Lecène and Moulonguet,[47] in 1924, reported 3 cases, 2 of the tumors being located on the fingers and 1 on a foot. They expressed the opinion that this tumor is a *tumeur d'origine dystrophique* and accepted the conservative method of treatment as that of choice.

The tumor described by Vermooten [48] in 1925 involved the proximal phalanx of the right thumb and was a typical xanthoma. It may well be that this tumor first involved the tendon sheath and secondarily invaded the diaphysis of the bone. Since it is not known whether this tumor was primary in the tendon sheath, it was not included in the present paper.

In 1927, Mason and Woolston [49] reviewed the previous literature, reported numerous cases from the records of others and added 8 personally observed cases of what they called "giant-cell xanthomatous tumor." They emphasized the benign character of this type of growth and discussed the clinical and pathologic picture, but they advanced no new ideas concerning its causation or pathogenesis. Janik, [50] in 1927, reported 14 cases collected from the literature, which have already been alluded to here. In the same year, Harbitz [51] described 11 new cases and after a review of the literature came to the conclusion that the growths should be classified as real tumors, probably sarcomas but comparatively benign.

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45. Weber, F. P.: Cutaneous Xanthoma and "Xanthomatosis" of Other Parts of the Body—Pituitary Xanthomatosis—"Xanthomyelomata" of Tendon-Sheaths, etc.—and the "Cholesterin Diathesis," Brit. J. Dermat. **36**:335-370 (Aug.-Sept.) 1924.

46. Miller, E. M.: The Surgical Aspect of Xanthoma Tumors, Ann. Surg. **80**: 256-267 (Aug.) 1924.

47. Lecène, P., and Moulonguet, P.: Les tumeurs à myéloplaxe des gaines tendineuses, Ann. d'anat. path. **1**:393-411 (July) 1924.

48. Vermooten, V.: Xanthosarcoma of Thumb: A Central Benign Giant-Cell Tumor of the Proximal Phalanx of the Thumb, Ann. Surg. **81**:851-856 (April) 1925.

49. Mason, M. L., and Woolston, W. H.: Isolated Giant Cell Xanthomatic Tumors of the Fingers and Hand, Arch. Surg. **15**:499-529 (Oct.) 1927.

50. Janik, A.: Tumors of Tendon Sheaths, Ann. Surg. **85**:897-911 (June) 1927.

51. Harbitz, F.: Tumors of Tendon Sheaths, Joint Capsules and Multiple Xanthoma, Arch. Path. **4**:507-527 (Oct.) 1927.

Segovia and Llompart,[52] in 1928, reported 2 tumors of the flexor tendon sheaths of the hand, and in the following year Eisen[53] and Kurtz[54] each described 1, both of which were located on an upper extremity. Eisen described his as a giant cell tumor and concluded that the accompanying bony defect observed in the proximal phalanx of the index finger was due to pressure from the tumor and not to an infiltrative process, for it was completely filled in with new bone twenty months later. Kurtz[54] expressed the opinion that the benign character and structure of this variety of tumor suggest that it may arise from a local inflammatory process connected with trauma and some peculiar disturbance of local lipoid metabolism.

During the same year, Geschickter and Copeland[55] added 27 cases collected at the Johns Hopkins Hospital. Two of these had already been reported by Bloodgood[23] in 1903 and 2 by Landois and Reid[35] in 1914. One patient in this group had 2 tumors involving the flexor tendon sheaths of the index and ring fingers, making a total of 24 tumors. Geschickter and Copeland[55] advanced the opinion that this type of tumor is derived from the sesamoid bones. They cited Pfitzner, who had shown that the sesamoids are most frequent on the first, second and fifth digits of the hand and foot, at the metacarpophalangeal or metatarsophalangeal joints, where giant cell tumors of the tendon sheaths are most commonly found, but that they may occur at the sites of these joints or the interphalangeal articulations in any of the fingers and toes. Other sites for the sesamoids may be in the tendons about the elbow, knee or ankle, in the tendon of the psoas muscle at the pubis and occasionally in the tendon of the gluteus maximus muscle near the head of the great trochanter. They continued: "When giant cell tumors of the tendon sheaths are examined microscopically a variant of the typical giant cell structure is seen, characterized by an unusual amount of pink-staining fibrous tissue, enclosing in a network cells of the cartilage type. This fibroid substance on further investigation is identified as the vestige of white fibrocartilage from which the sesamoid bones are derived." Tumors studied by them which did not occupy the site of these bones did not show the characteristic giant cell structure, and they concluded, therefore, that such growths should be classified as fibrohemangiomas, fibromas or ganglions.

52. Cited by Gonzalez-Aguilar, J.: Contribution to the Pathology of Tendon Tumors of Giant Cells, J. Bone & Joint Surg. **12**:280-288 (April) 1930.

53. Eisen, D.: Giant-Celled Tumors of Tendon Sheaths, Am. J. Surg. **7**:120-123 (July) 1929.

54. Kurtz, A. D.: Xanthoma of Tendon Sheath, Am. J. Surg. **7**:862-864 (Dec.) 1929.

55. Geschickter, C. F., and Copeland, M. M.: Osteitis Fibrosa and Giant Cell Tumor, Arch. Surg. **19**:169-271 (Aug.) 1929.

During the period from 1920 to 1929, 99 undoubted xanthomas of the tendon sheaths were reported in the literature. This group, added to the previously reported 106, makes a total to the end of 1929 of 205.

1930 to 1938: In 1930 three authors each reported 1 tumor and listed it as a giant cell tumor of the tendon sheaths. Bessesen's [56] tumor, which had appeared after an injury, was situated on the right middle finger. Dudley's [57] was located on the left ring finger. The third tumor, reported by Gonzalez-Aguilar,[58] was attached to the infrapatellar tendon and is the only tumor in that location that has been described in the literature up to the present time.

Ragins,[10] in 1931, recorded 2 more growths, both located on the feet. He felt that they should be known as benign tumors of the tendon sheaths but added that if giant cells and foam cells had been present they would have been classified as benign xanthomatous giant cell tumors of the tendon sheaths. He stated the opinion that the tumor is a true neoplasm of mesothelial origin, not a granuloma and not associated with a generalized disturbance of cholesterol metabolism or hypercholesteremia.

Six additional tumors were reported in 1932, 1 by Görög,[59] who expressed the opinion that it should be listed as a true neoplasm and not as a granuloma. Bellelli [60] reported a tumor located on the dorsum of the left wrist; Einaudi,[61] 2 growths which he called giant cell tumors and which were allied with the tendon sheaths of the ring finger and the popliteal space. He expressed the belief that the presence of xanthoma cells in such tumors is the result of a disturbance in cholesterol metabolism. Jebens,[62] retaining the term myeloma, recorded a growth situated on the flexor and extensor tendon sheaths of the left little finger,

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56. Bessesen, D. H.: Xanthoma, So-Called Giant Cell Tumor of the Tendon Sheath: Case Report, West. J. Surg. **38**:701, 1930; abstracted, Am. J. Cancer **15**:1894 (July) 1931.

57. Dudley, H. D.: Giant Cell Tumors of Tendon Sheaths, Northwest Med. **29**:217-219 (May) 1930.

58. Gonzalez-Aguilar, J.: Contribution to the Pathogeny of Tendon Tumors of Giant Cells, J. Bone & Joint Surg. **12**:280-288 (April) 1930.

59. Görög, D.: Ueber die Riesenzellengeschwülste der Sehnenscheiden, Centralbl. f. allg. Path. u. path. Anat. **53**:341-347 (Jan.) 1932.

60. Bellelli, F.: Su di un tumore delle guaine tendinee, Riforma med. **48**:630-635 (April 23) 1932.

61. Einaudi, M.: Sui tumori a cellule gigante delle guaine tendinee, Minerva med. **1**:702-708 (May 19) 1932; abstracted, Am. J. Cancer **18**:785 (July) 1933.

62. Jebens, E. H.: Myeloma of Tendon Sheath, Proc. Roy. Soc. Med. **25**: 1098-1099, 1932.

and he refused to accept the hypothesis of the inflammatory origin of this tumor. The sixth tumor was reported by Sprenger,[63] a German writer.

Canavero,[64] in 1934, added 2 digital tumors. Duany [65] reported 3, 2 involving the tendon sheaths of the fingers and 1 fastened to a semitendinosus sheath. In the same year, Geschickter and Lewis [66] added 23 more. The exact details concerning these tumors are lacking, but the authors stated that the majority were located on the fingers, near the metacarpophalangeal and interphalangeal joints, usually on the flexor surface, and that remainder were found chiefly on the hands or about the ankles and feet. They again advanced the hypothesis that these tumors are derived from the sesamoid bones. Morton [67] also recorded 6 tumors during that year; 4 appeared on the tendon sheaths of the fingers and 2 on the tendon sheaths about the ankle. He classified them under the general heading of synoviogenic tumors having their origin in the synovial membrane of tendons, bursae, joint capsules and joint linings.

In 1935, Bussebaum [68] added 2 cases and said that these tumors are benign granulation tumors that develop in the same way as does any inflammatory growth. The following year, Wahlgren [69] described 19 additional tumors, reports of 9 having been collected from Bergstrand. Thirteen of these tumors involved tendon sheaths and 6 the synovial membranes of joints. Of the 13 tumors involving tendon sheaths 1 patient had 2, 1 on the left first and 1 on the left fourth toe. Zumtobel,[70] in 1936, recorded 4 more tumors and stressed their benign character but denied that they had any relation to trauma or infection.

63. Sprenger, W.: Zur Kenntnis der xanthomatösen Riesenzellgranulome der Sehnenscheiden, Arch. f. klin. Chir. **169**:683-687, 1932.

64. Canavero, M.: Contributo allo studio e alla conoscenza dei tumori delle guaine tendinee, Policlinico (sez. chir.) **41**:341-361, 1934.

65. Duany, N. P.: Tumores de las vainas tendinosas y tendones, Rev. de med. y cir. Habana **39**:780-790, 1934.

66. Geschickter, C. F., and Lewis, D.: Tumors of Tendon Sheaths, Joints and Bursae, Am. J. Cancer **22**:96-126 (Sept.) 1934.

67. Morton, J. J.: Tumors of the Tendon Sheaths: Their Close Biological Relationship to Tumors of the Joints and Bursae, Surg., Gynec. & Obst. **59**:441-452 (Sept.) 1934.

68. Bussebaum, G.: A Contribution on Inflammatory Tumors Presenting the Picture of Malignant Tumors, with a Consideration of So-Called Giant-Cell Sarcoma of the Tendon Sheaths, Dissert., Halle-Wittenberg, 1935; abstracted, Internat. Abst. Surg. **62**:368 (April) 1936.

69. Wahlgren, F.: Ueber die von Sehnenscheiden und Gelenkkapseln ausgehenden sog. Riesenzelltumoren mit besonderer Berücksichtigung der Pathogenese, Acta path. et microbiol. Scandinav., 1936, suppl. 26, pp. 77-89.

70. Zumtobel, M.: Beitrag zur Klinik und Pathologie der gutartigen Sehnenscheidentumoren mit besonderer Berücksichtigung der xanthomatösen Riesenzellengeschwülste, Deutsche Ztschr. f. Chir. **247**:501-516 (Sept. 7) 1936.

Gömöri [71] added another, found on the second toe of a woman 30 years of age. He stated that these locally situated tumors that have such a great similarity to giant cell tumors of bone are never associated with any alteration in cholesterol metabolism.

Pique, Brachetto-Brian and Fasciolo,[72] in 1937, described 2 more tumors, both in women and attached to the tendon sheaths of the thumb and the anterior surface of the wrist. The authors classified them as benign tumors containing giant cells.

In 1938, Thannhauser and Magendantz [73] gave an excellent review of the general subject of xanthomatous lesions and presented 2 cases of tendon sheath involvement. The patient in the first was a woman with multiple nodular involvement of the fingers, ankles and right elbow. The patient in the second was a man, a brother of the former patient, who had a xanthoma of the extensor tendon sheath of the right fourth finger and also xanthomatous involvement of both achilles tendons with associated arthritic nodules in the fingers. Thannhauser and Magendantz [73] classified these tumors under the heading of the primary essential xanthomatoses.

Lasher,[74] in 1938, described a xanthoma attached to the extensor tendon sheath of the right middle finger in a woman 53 years of age. The tumor had been present for eight years; it was successfully excised.

From 1930 until 1938, 70 more undoubted xanthomas of the tendon sheaths were cited in the literature. These, together with the 205 already reported, make a grand total of 275 reported since the first case of Broca [15] in 1860 and cover a period of seventy-nine years, making an average of about three to four each year. Of the probable xanthomas 16 have been listed.

Synovial Membranes.—1865 to 1899: The first xanthoma of the synovial membrane of the joints was reported by Simon [75] in 1865. This tumor was of the solitary, pedunculated variety and was successfully excised from the knee of a man 46 years of age. Microscopically

71. Gömöri, G.: Three Uncommon Tumors, Am. J. Surg. **33**:150-156 (July) 1936.

72. Pique, J. A.; Brachetto-Brian, D., and Fasciolo, J. C.: Tumores benignos de las vainas tendinosas digitales, Rev. ortop. y traumatol. **7**:169-181 (Oct.) 1937.

73. Thannhauser, S. J., and Magendantz, H.: The Different Clinical Groups of Xanthomatous Diseases: A Clinical Physiological Study of 22 Cases, Ann. Int. Med. **11**:1662-1746 (March) 1938.

74. Lasher, W. W.: Industrial Surgery: Principles, Problems and Practice, New York, Paul B. Hoeber, Inc., 1938, p. 46.

75. Cited by Hartman, F. W.: Synovial Membrane Tumors of Joints, Surg., Gynec. & Obst. **34**:161-167 (Feb.) 1922, and by Razemon, P., and Bizard, G.: Les tumeurs primitives des articulations, Rev. de chir., Paris **69**:229-266, 1931.

it revealed pigmented cells, large giant cells and foam cells and was diagnosed as a hypertrophied sarcomatous synovial fringe. The next one to appear was described by Annandale [76] in 1886. It too was a pedunculated growth and was classified as a myeloid sarcoma, but no recurrence followed local excision. In 1886, Weir [77] added another pedunculated giant cell sarcoma located in the synovial membrane of a knee.

1900 to 1909: The first diffuse xanthoma was reported by Moser [75] in 1903. It involved the synovial membrane of the left tibiotarsal articulation. Moser called this tumor a giant cell sarcoma; it was an extensive lesion and was successfully excised. There was no evidence of recurrence after seven years of observation.

1910 to 1919: Dowd,[78] in 1912, under the title "villous arthritis of the knee," was the first writer to describe a diffuse xanthoma of the synovial membrane of the knee. This lesion occurred in a man aged 33 who had had swelling and moderate disability of the knee for four years. When the joint was opened, marked hypertrophy of the membrane was seen, one piece measuring 2 by 1.5 inches (5 by 4 cm.). The patient recovered after excision of many of the villi. In spite of this, the author diagnosed the growth as a giant cell sarcoma, but it seems likely that now it would be classified as a xanthoma, and it will be considered as such in this article.

In 1914, 1 additional pedunculated tumor of the tarsal joints was reported by Weil,[79] and in 1917, Züllig [79] added a diffuse xanthoma of the right knee.

1920 to 1929: In 1921, Blanco,[80] at the Mayo Clinic, reported a pedunculated growth arising in the synovial membrane of the left knee and emphasized its similarity to the tumors described by Broders [38] as benign xanthic extraperiosteal foreign body giant cell tumors of the extremities involving tendon sheaths.

A review of the literature was published by Hartman [81] in 1922, and to the cases recorded he added 1 observed by him. The patient was a

76. Cited by Turner, A. L.: Primary Sarcoma of the Synovial Membrane, Lancet **2**:54 (July 7) 1894.

77. Cited by Hartman, F. W.: Synovial Membrane Tumors of Joints, Surg., Gynec. & Obst. **34**:161-167 (Feb.) 1922.

78. Dowd, C. N.: Villous Arthritis of the Knee (Sarcoma), Ann. Surg. **56**: 363-365 (Aug.) 1912.

79. Cited by Razemon, P., and Bizard, G.: Les tumeurs primitives des articulations, Rev. de chir., Paris **69**:229-266, 1931.

80. Blanco, P.: Giant Cell Tumor in the Knee Joint: Report of a Case, J. Orthop. Surg. **3**:156-157 (April) 1921.

81. Hartman, F. W.: Synovial Membrane Tumors of Joints, Surg., Gynec. & Obst. **34**:161-167 (Feb.) 1922.

man 20 years of age. Symptoms had been present for four years. Frequent aspirations of bloody fluid from the knee had been done for some time prior to operation. Hartman [81] concluded that it seemed best to place these lesions with the benign tumors of connective tissue origin, and he preferred the name myeloid tumor. He stated, however, that there is always a potentiality of malignancy. In addition, he discussed the pathologic picture and stated that three types of cells are observed microscopically: namely, round cells, foreign body giant cells and foam cells. He added, "Too much importance has been given the foam cell and the giant cell in the classification of this group since both may be absent from otherwise typical tumors arising in the synovia."

Seyler,[40] in the same year, added a tumor (under the name of *xanthomatische Granulome)* which was located in one of the tarsal joints.

In 1923, 2 more tumors of the local variety were observed, one by Mühe,[79] in the synovial membrane of the tarsal joints, the other by Paitre and Bruas,[82] situated in the left knee.

Garrett, [43] in 1924, reported 3 cases, but from his article one receives the impression that the tumors involved not only the synovial membrane but the bony articulations, and it is difficult to say whether they were true xanthomas, primary in the synovial membrane; they were, therefore, discarded from this review. During the same year another pedunculated xanthoma was reported by Largiader,[79] which involved the synovial membrane of a knee. The following year two more circumscribed tumors were reported, one by Wustmann [83] and the other by Kuozkowski.[79]

Judy,[84] in 1926, recorded a diffuse xanthoma of the left knee that had resulted from the intra-articular injection of 2 per cent solution of formaldehyde three years prior to synovectomy. Koch [85] observed a similar tumor that had recurred after a partial synovectomy.

Harbitz [51] in 1927 described a diffuse xanthoma in a woman 20 years of age. The tumor, he stated, resembled the xanthosarcomas of

82. Cited by Faulkner, D. M.: Primary Synovial Membrane Tumors of Joints, Surg., Gynec. & Obst. **53**:189-195 (Aug.) 1931.

83. Wustmann, O.: Beiträge zur frage der xanthomatischen Riesenzellneubildungen, Deutsche Ztschr. f. Chir. **192**:381-400 (Aug.) 1925; abstracted, J. A. M. A. **85**:1100 (Oct. 3) 1925.

84. Judy, J. A.: Discussion, Boston M. & S. J. **194**:28-29 (Jan. 7) 1926.

85. Cited by Razemon, P., and Bizard, G.: Les tumeurs primitives des articulations, Rev. de chir., Paris **69**:229-266, 1931, and by Kling, D. H., and Sashin, D.: Hemorrhagic Villous Synovitis of the Knee Joint Due to Xanthoma: Report of a Case, Arch. Surg. **30**:52-61 (Jan.) 1930.

the tendon sheaths. Included in the reports of 1927 were 2 more lesions, a diffuse type seen by Herscheiner,[79] and one of the local variety recorded by Tobler.[79] Both involved the synovial membrane of the knee.

The literature in 1928 revealed 6 additional growths, 3 of which, pedunculated and occurring in the knee, were reported by Abadie,[86] Wegelin [79] and Simon [75] respectively. Two were of the diffuse form; 1 was reported by Frangenheim,[79] and the other by Mandl.[87] The sixth, a pedunculated tumor of the ankle, was reported by Paitre and Talbot.[88] Similarly, Simon [75] described a pedunculated tumor in the right knee of a man 59 years of age. Paitre and Talbot [88] described these tumors as made up of dense inflammatory tissue in which are seen three types of cells: giant cells varying between those of bone and those seen in a tubercle, macrophagocytes containing blood pigment and lipoid or xanthoma cells.

In 1929, Négrié and Canton [89] added another circumscribed tumor of the knee in a man aged 20 which they felt to be a benign giant cell tumor of the synovial membrane. During the same year, Sundt [79] recorded a synovectomy done for the removal of a diffuse xanthoma, similarly located.

1930 to 1938: In 1930, Sonntag [90] reported a recovery from a simple excision of a pedunculated tumor in a knee.

Faulkner,[91] in 1931, reviewed the literature and added to the xanthomas recorded 2 tumors of the synovial membrane of the knee. These tumors were pedunculated and large. He reserved for them the French term, used by Heurtaux, Talbot and others, *tumeur à myeloplaxes,* or myeloplaxoma. He discussed the pathologic picture of these growths and emphasized Talbot's description as an accurate one. He added that there is no histologic evidence of malignancy but concluded that if recurrence takes place after conservative operation a high amputation should be done immediately.

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86. Abadie, J.: Tumeur à myéloplaxes de la synoviale du genou. Tumeur à myéloplaxes de la rotule. Accessoirement, une vieille erreur de pronostic, Bull. et mém. Soc. nat. de chir. **54**:341-346, 1928.

87. Mandl, F.: Cited by Kling, D. H., and Sashin, D.

88. Cited by Faulkner, D. M.: Primary Synovial Membrane Tumors of Joints, Surg., Gynec. & Obst. **53**:189-195 (Aug.) 1931, and by Razemon, P., and Bizard, G.: Les tumeurs primitives des articulations, Rev. de chir., Paris **69**:229-266, 1931.

89. Négrié and Canton: Tumeur à myéloplaxes de la synoviale du genou, Bull. et mém. Soc. nat. de chir. **55**:617-619, 1929.

90. Sonntag: Ueber intraartikuläre Xanthome des Knies, Deutsche Ztschr. f. Chir. **223**:346-359 (March) 1930.

91. Faulkner, D. M.: Primary Synovial Membrane Tumors of Joints, Surg., Gynec. & Obst. **53**:189-195 (Aug.) 1931.

In the same year, Razemon and Bizard [92] reviewed and discussed all the benign and malignant tumors of the synovial membrane. Of the 45 benign tumors they found 26 to be xanthomatous; they failed, however, to add any new cases of their own. They again emphasized the three typical histologic findings, foam cells, foreign body giant cells and collections of ocher pigment, and expressed the view that small trauma plus minute hemorrhages is the basis for the evolution of these growths.

In 1933, Bonn [93] added a diffuse growth observed in a woman 26 years old. It involved the synovial membrane of the left knee and resulted from a previous injury. He pointed out that xanthomatous deposits may occur in any tissue when there is an excess of total blood lipoid and that such deposits are likely to occur in granulation tissue.

Kling and Sashin,[94] in 1935, reported the result of a synovectomy done for "hemorrhagic villous arthritis of the knee joint due to xanthoma." They also reviewed the literature and concluded that these tumors are benign.

Wahlgren, in his article on both the "tendon sheath type" and the "synovial membrane type" of xanthoma, added 6 more; 5 involved the knee and 1 the right tibiotarsal articulation.

In 1936, Geschickter and Copeland [95] recorded 4 xanthomatous lesions within the synovial membrane of the knee and a fifth about the elbow joint and associated with diabetes. They explained that xanthomatous giant cell tumors of joints are histologically similar to giant cell tumors of tendon sheaths, basing this opinion on the following explanation:

> The original condensation for the future sesamoid bone buds from the joint side of the future bone, just beneath the tendinous attachment. An abortive formation of this sesamoid type, undergoing resorption by giant-cell proliferation, may give rise to a xanthomatous giant-cell tumor within the joint. Later when the same embryonic sesamoid focus has migrated to its final position within the tendon sheath a similar resorption by giant-cell proliferation gives rise to a tumor of the tendon sheath. Whether the tumor is of tendon sheath or synovial origin, the typical fibrocartilaginous structure of the sesamoid bone may be found remaining in the tumor.

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92. Razemon, P., and Bizard, G.: Les tumeurs primitives des articulations, Rev. de chir., Paris **69**:229-266, 1931.

93. Bonn, R.: Xanthom des Kniegelenks als Unfallfolge, Arch. f. orthop. u. Unfall-Chir. **33**:146-148, 1933; abstracted, Am. J. Cancer **20**:777-778 (March) 1934.

94. Kling, D. H., and Sashin, D.: Hemorrhagic Villous Synovitis of the Knee Joint Due to Xanthoma: Report of a Case, Arch. Surg. **30**:52-61 (Jan.) 1930.

95. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone (Including the Jaws and Joints), Am. J. Cancer **26**:747-752, 1936.

Since the first tumor was reported in 1865, and covering a period of seventy-four years (to and including 1938), 43 lesions of the synovial membrane have been described in the literature, making an average appearance of approximately one tumor in two years.

Statistical Analysis.—All the available literature since about 1850 has been reviewed, and it is felt that practically all the reported cases are referred to here. Complete data were not always available, but statistics have been compiled on a sufficient number of cases to enable one to arrive at certain definite conclusions. These tumors have heretofore masqueraded under so many names that at times it was difficult to decide to what group of pathologic entities they actually belonged. In some instances it was felt that certain ones belonged to the group of benign xanthomas in spite of the previously expressed opinions, and these tumors have been classified under the heading of probable xanthomas. When complete evidence was lacking as to their true nature or when the evidence pointed toward malignant or otherwise diverse characteristics, the growths were discarded. Of 36 doubtful lesions, 20 were of the latter class and had been diagnosed under such names as fusocellular, globocellular or fibrofusocellular sarcomas, fibromyxosarcomas or melanotic sarcomas. The duration of these tumors had been comparatively short, the growth had been fairly rapid, recurrence had been early or other such similar evidences of the presence of malignant changes not consistent with the true nature of xanthoma had been present.

In the cases collected from the literature there were 317 patients with 327 tumors; 274 had involvement of the tendon sheaths and 43 had involvement of the synovial membranes. Two hundred and sixty-nine patients with growths in the tendon sheaths had 1 tumor each; 3 patients had 2 tumors each; one patient had 3, and in 1 there were 6 tumors. Of the group with tumors of the synovial membranes each patient had involvement of only one joint.

The sex was recorded in 236 instances, 129 of the patients being women and 107 men, or 55 per cent women and 45 per cent men. In 220 instances the age and sex were both recorded; of this number 119, or 54 per cent, were women and 101, or 46 per cent, were men. In 3 cases the age but not the sex was reported, making a total of 223 in which the age was listed. The average age of the 119 women was 37.3 years, and that of the 101 men was 38 years. The average age for the entire group was 37.5 years. Arranged by decades, the largest group fell in the third, with 61, the fourth running second with 44. The oldest patient was a man 82 years old, reported by Malherbe,[11] the youngest a patient aged 5 years, of unspecified sex, recorded by Garrett.[43]

In 156 cases the duration of the tumor was cited. One hundred and thirty-three tumors involved the tendon sheaths, with an average duration of five years and four months. Twenty-three involved the synovial membranes, with an average duration of three years and eleven months. For the entire group the average duration was five years and one month. The shortest duration was three weeks (the patient had a tumor on the tendon sheath of the right middle finger; the case was reported by Bessesen).[56] The longest was thirty-one years, recorded by Fritsch,[11] the patient having a growth involving a tendon sheath of the right foot.

The size of the tumor was recorded in 109 cases. This was not always the exact size in inches or centimeters, but a comparative one, from which an attempt was made to reconstruct the measurement as nearly as possible into centimeters. Of 66 tumors connected with the tendon sheaths of the upper extremity the average size was approximately 2 by 1 cm. In the lower extremity, involving the tendon sheaths, 27 tumors showed an average size of 5.5 by 4 cm. The average for both was 3 by 2 cm. Of 16 tumors of the synovial membranes the average size was 3.5 by 2.5 cm. The average size for the entire group was about 3 by 2 cm. The largest tumors were those located about the foot and ankle; two or three of these were as large as 9 by 7 cm. The smallest were those involving the fingers; the smallest of these was approximatley 0.5 cm. in diameter.

The records are not complete as to the presence or absence of trauma. Of the 327 cases studied, a definite record of injury could be found in only 61, or 19 per cent. Of this group, trauma was referred to 48 times in the cases of tumor of the tendon sheaths, or 17 per cent. In 13, or 30 per cent of cases of tumor involving the synovial membranes a definite history of previous trauma was obtained. Of the complete group of tumors reported, 166 had no connection with injury or absence of injury. Thus, since the presence or absence of trauma is not cited in over half of the cases, the aforementioned figures could be markedly altered in either direction if more complete information were available, and therefore it would appear that they are not of much real value from the statistical standpoint.

The occupation of the patients was stated in only a few instances.

The location of 62 of the 327 tumors was not recorded, leaving 265 for which definite positions were stated. One hundred and forty-one, or 53 per cent, involved the tendon sheaths of the fingers, of which 72, or 51 per cent, were located on the flexor surface. Thirty-four of these were on the right hand and 19 on the left; in 19 instances the extremity was not indicated. The extensor surface was involved 18 times (13 per cent), the tumor being on the right hand 11 times, on the left 5 times and on an unspecified finger twice. Of the remaining group, 39, or 28 per cent, were not given a definite position as to sur-

face, and in 12, or 9 per cent, the tumor was located on the medial surface, the lateral surface or a combination of these surfaces. Of the group that was not given a definite position as to surface 14 were on the right hand, 7 on the left, and in 18 the side was not indicated. In the miscellaneous group, the right side was involved 6 times and the left once; in 5 instances the side was not indicated. The index finger was the most common site, 37, or 26 per cent of the tumors occurring there. The right index finger was involved 19 times and the left 8 times; in 10 instances the side was not stated. The middle finger was next, with 30 tumors, or 21 per cent. The right side was affected 18 times and the left 6 times; in 6 instances the side was not indicated. The rest of the fingers followed in order, the little finger showing the least incidence. Of the 141 tumors there was involvement of the fingers of the right hand in 65 and of those of the left in 32. In 44 instances the extremity was not designated.

It appears that the tumors were about equally distributed as to the level at which they occurred on the fingers. However, in most instances—in fact, in 86 of the 141, or 60 per cent—no level as to position in relation with the phalanges was given; thus it is impossible to arrive at any positive conclusion concerning this point.

Of the 81 remaining tumors of the tendon sheaths of which the position was known, 37 appeared about the foot and ankle, most often on the right side and on the extensor surface. Sixteen occurred on parts of the hand other than the fingers, 13 on the toes, 10 about the wrist, 3 on tendon sheaths about the knee, and 1 each on the leg and elbow. Of this group 30 occurred on the flexor surface, 23 on the extensor, 7 on the lateral, 6 on the medial, 1 on the medial and lateral; in 14 instances the surface was not recorded. Of the 222 tumors of known location involving the tendon sheaths, 102 were on the flexor surface, 41 on the extensor, 11 on the lateral, 9 on the medial, 4 on the flexor and extensor, and 1 on the medial and lateral; 1 included all surfaces, and in 53 instances the surface was not indicated. Of this group, 99 were on the right extremities and 56 on the left; in 67 instances the side was not indicated.

Of the 43 tumors of the synovial membranes 13 were diffuse and 26 were pedunculated. Thirty-seven involved the knee, 3 the ankle and 3 the tarsal articulations. Fourteen were on the right, and 18 on the left. In 11 instances the side was not mentioned.

In the entire group of tumors of both the synovial membrane and tendon sheath, the right side was involved 113 times and the left 74 times; in 78 instances the side was not indicated. One hundred and sixty-eight tumors were on the upper extremity, of which 76 were on the right side, and 41 on the left; in 51 instances the side was not speci-

fied. Ninety-seven were on the lower extremity, involving the right side 37 times and the left 33 times; in 27 instances the side was not specified.

Of the 327 tumors reported in the literature, a record of treatment was observed for 243 tumors of the tendon sheaths and for 35 tumors of the synovial membranes, making a total of 278 tumors treated. Local excision was done for 229 tumors of the tendon sheaths, excision and cautery for 2, excision and roentgen therapy for 1, and amputation for 11. Of the tumors of the synovial membrane, local excision was completed for 24, local excision plus roentgen therapy for 2, synovectomy for 6 and partial synovectomy for 3.

A record of a follow-up was found in only 153 instances; recurrence was reported in 25, or 16 per cent. Among 18 tumors of the synovial membrane there were 5 recurrences and of 135 tumors of the tendon sheaths, 20 recurred.

A record of the values for blood cholesterol was found in only a very few of the cases. Mason and Woolston [49] reported the cholesterol content of the blood in 3 cases, with readings of 96 mg., 98 mg. and 131 mg. per hundred cubic centimeters in the first; 165 mg. and 143 mg. in the second, and 185.3 mg. in the third. Ragins [10] reported the results of chemical examination of the blood in both of his cases. The concentration of cholesterol was 147 mg. per hundred cubic centimeters of blood in the first and 177 mg. in the second. Görög [59] reported a value for blood cholesterol of 131 mg. per hundred cubic centimeters in his only case. Zumtobel [70] reported the value for cholesterol in all 4 of his cases; these values were 180 mg., 130 mg., 245 mg., and 280 mg. per hundred cubic centimeters respectively. Thannhauser and Magendantz [73] found the value for blood cholesterol to be 200 mg. and that for cholesterol esters 160 mg., with a value for total cholesterol of 360 mg., in their first case. In the second the value for cholesterol was 107 mg., that for cholesterol esters 103 mg. and that for total cholesterol 210 mg. These authors were the only ones to report a chemical analysis of any of the tumors; the report for the first case was: total cholesterol, 9 mg., and total phosphatides, 11 mg. per hundred cubic centimeters. Thus, only twelve reports of chemical study of the blood could be found in the literature.

MATERIAL OF PRESENT STUDY

Since 1919, 70 patients have presented themselves at the Mayo Clinic with one or more xanthomas of the extremities involving tendon sheaths or synovial membranes (table 1). Of this group 50, or 71 per cent, were women and 20, or 29 per cent, were men. The average age of the women was 45 years, and that of the men, 43 years. The average age of the entire series was 44. A man and a woman aged 68 were the oldest patients; a boy of 16 was the youngest. Twenty-two

TABLE 1.—*Xanthoma of Tendon Sheaths and Synovial Membranes*

Case	Sex	Age	Duration	Size	Trauma	Infection	Location	Treatment	Result
1	F	48	2 years	1.5 by 1 cm.	....	Yes	Proximal phalanx of left middle finger.....	Local excision	No recurrence
2	F	56	Several years	1.5 cm., 1 cm.	....	Yes	Proximal phalanx and distal phalanx of right index finger	Local excision and roentgen therapy	Two subsequent excisions, 4 and 6 months later; recurrence again in 1938
3	F	61	.....	3 by 1 by 1 cm.	....	No	Fourth flexor tendon sheath of palm of right hand	Local excision	No recurrence
4	F	42	1½ years	1.5 by 0.5 cm.	Yes	No	Proximal phalanx (flexor surface) of right ring finger	Local excision	No recurrence
5	F	49	3 years	1 by 0.5 cm.	Yes	No	Distal phalanx of left little finger.....	Local excision	No recurrence
6	F	47	5 years	1 by 1 cm.	No	No	Proximal phalanx (lateral surface) of right middle finger	Local excision	No recurrence; tumor excised (left index finger) at home
7	F	49	6 years	12 by 12 mm.	No	No	Distal phalanx (flexor surface) of right little finger	Local excision	No recurrence
8	M	63	Several years	1 by 1 cm.	No	No	Proximal phalanx (lateral surface) of left index finger	Local excision	No recurrence
9	F	67	2½ years	2 by 1 cm.	Yes	No	Middle phalanx (flexor surface) of left middle finger	Local excision	?
10	M	21	3 months	3 by 1 cm.	....	No	Middle phalanx (flexor surface) of left middle finger	Local excision	Died
11	F	43	1 year	1 by 1.5 cm.	....	No	Flexor surface, interphalangeal joint, of right thumb	Local excision	No recurrence
12	F	38	3 years	1 by 1.5 cm.	Yes	No	Extensor surface of distal joint of right middle finger	Local excision	No recurrence
13	M	53	6 years	13 by 6 by 5 cm.	....	No	Tendon sheaths of right internal and external hamstrings	Local excision and roentgen therapy	Second excision here 3 months later; died cause unknown
14	M	52	.....	.....	....	Yes	Right ring finger.....	Local excision	No recurrence
15	M	56	6 years	.....	Yes	No	Right posterior tibial and peroneal tendon sheaths and sole of foot	Local excision and roentgen therapy	Recurred 3½ mo. later; unknown result after 2d excision
16	M	53	3 years	2.5 by 2.5 cm.	No	No	Flexor surface of interphalangeal joint of right thumb	Local excision	Recurred
17	F	43	4 months	7 by 7 mm.	Yes	No	Extensor surface of distal joint of left ring finger	Local excision and roentgen therapy	No recurrence
18	M	63	28 years	2.5 by 1.5 cm.	Yes	No	Extensor surface of proximal phalanx of left middle finger	Local excision	No recurrence
19	F	42	.....	18 by 11 mm.	....	No	Flexor surface of distal phalanx of right little finger	Local excision	Recurred
20	F	31	2 years	3 by 2 cm.	Yes	No	Left anterior tibial tendon sheath.....	Local excision; 1 roentgen treatment	No recurrence
21	F	52	2 years	1.5 by 1.5 cm.	Yes	No	Extensor surface of distal phalanx of left index finger	Local excision	No recurrence
22	F	40	12 years	22 by 18 cm.	Yes	No	Suprapatellar pouch of left knee.....	Excision of suprapatellar pouch	No recurrence
23	M	50	3 months	1.5 by 1.5 cm.	....	No	Flexor surface of distal phalanx of right thumb....	Local excision	?
24	F	43	1 year	1 by 1 cm.	Yes	No	Extensor surface of distal phalanx of left index finger (recurrent)	Local excision	No recurrence
25	F	58	12 years	2.5 by 2.5 cm.; 2 by 2 cm.	....	Yes	Two tumors; left knee.....	Local excision	?
26	F	62	1 year	1 by 1 cm.	....	No	Flexor surface of middle phalanx of right middle finger	Local excision	No recurrence
27	F	62	1 year	1 by 1 cm.	....	No	Flexor surface of distal phalanx of right middle	Local excision	?

			1 year	1 by 1 cm.	Yes	No	Extensor surface of distal phalanx of right thumb....	Local excision	?
							Extensor surface of distal phalanx of left index finger (recurrent)	Local excision	No recurrence

25	F	58	12 years	2.5 by 2.5 cm.; 2 by 2 cm.	....	Yes	Two tumors; left knee.....	Local excision	?
26	F	62	1 year	1 by 1 cm.	....	No	Flexor surface of middle phalanx of right middle finger	Local excision	No recurrence
27	F	61	.....	1.5 by 1 by 0.5 cm.	....	No	Flexor surface of distal phalanx of right middle finger	Local excision	?
28	F	52	10 years	2.5 by 1.5 by 1 cm.	Yes	Yes	Flexor surface of distal phalanx of left middle finger	Local excision	No recurrence
29	F	30	8 years	2.5 by 2 by 1 cm.	Yes	No	Flexor surface of distal phalanx of right thumb (recurrent)	Local excision	No recurrence
30	F	51	2 years	2 by 2 cm.	....	No	Distal joint of left middle finger.....	Local excision	?
31	M	36	25 years	7 by 5 by 3 cm.	....	No	Tendon sheaths (anterior surface) of right ankle....	Local excision and roentgen therapy	No recurrence
32	F	50	16 years	1 by 1 cm.; 6 by 6 mm.	Yes	Yes	Flexor and extensor surfaces of distal phalanx of right index finger	Local excision	Appearance on other fingers
33	F	37	7 years	1.5 by 1.5 cm.	....	No	Flexor surface of middle phalanx of right middle finger	Local excision	No recurrence
34	F	63	18 months	1 by 1 cm.	No	Yes	Distal joint of left little finger (recurrent).....	Local excision	No recurrence
35	F	47	10 years	3 by 2 cm.	No	Yes	Flexor and extensor surfaces of middle phalanx of right middle finger	Local excision	No recurrence
36	M	30	3 years	4 by 4 mm.	Yes	No	Extensor surface of middle phalanx of right ring finger (recurrent)	Local excision	Recurred
37	F	42	2 months	1 by 0.5 cm.	....	No	Extensor surface of proximal phalanx of right middle finger	Local excision	No recurrence
38	F	49	5 years	7 by 7 mm.	Yes	No	Extensor and medial surfaces of distal phalanx of right middle finger	Local excision	Recurred 1 year later; 2d excision too recent
39	M	16	2 years	18 by 15 by 13 mm.	No	No	Extensor surface, over right 5th metacarpal head...	Local excision	No recurrence
40	F	29	15 years	.....	....	No	Right peroneal tendon (recurrent).....	Local excision at home; roentgen therapy	No recurrence
41	M	43	7 years	1 by 1 cm.	....	No	Extensor surface of middle phalanx of right ring finger	Local excision	No recurrence
42	M	68	5 years	2 by 2 cm.	....	No	Flexor surface of middle phalanx of right middle finger	Local excision	Appearance of 2 tumors in right palm
43	F	37	.....	2 by 1 cm.	....	No	Middle phalanx of left index finger.....	Local excision	No recurrence
44	M	50	10 years	1.5 by 1.2 by 0.9 cm.	Yes	No	Flexor surface of proximal phalanx of right little finger	Local excision	No recurrence
45	F	28	2 years	1 by 1 cm.	Yes	No	Right palm	Local excision	No recurrence
46	F	24	19 years	.....	Yes	No	Extensor surface of middle joint of right middle finger	Local excision	Recurred
47	F	53	1 year	1.5 by 1 cm.	....	No	Proximal phalanx of right ring finger.	Local excision	?
48	M	37	18 months	2 by 2 cm.	Yes	Yes	Extensor surface of interphalangeal joint of right great toe	Local excision	No recurrence
49	F	46	3 years	1.5 by 1.5 cm.	....	No	Flexor and extensor surfaces of distal phalanx of right middle finger	Local excision and roentgen therapy	?
50	M	43	1 year	0.5 by 0.5 cm.	Yes	No	Extensor surface of interphalangeal joint of left thumb	Local excision	No recurrence
51	M	19	3 years	1 by 1 cm.	Yes	No	Synovia of right knee.....	Local excision	No recurrence after 5 months

TABLE 1.—*Xanthoma of Tendon Sheaths and Synovial Membranes*—Continued

Case	Sex	Age	Duration	Size	Trauma	Infection	Location	Treatment	Result
52	F	30	4 years	7 by 7 mm.; 7 by 7 mm.	?	No	Flexor surface of proximal phalanx of right middle finger; flexor tendon sheath of right middle finger; palm of hand	Local excision	No recurrence after 4 months
53	F	20	1 year	6 by 4 by 1.5 cm.	No	No	Synovia of left knee	Local excision	No recurrence
54	F	59	1 month	2.5 by 1.5 by 1 cm.	Yes	Yes	Flexor surface of distal phalanx of right index finger	Local excision	No recurrence
55	M	28	7 years	3 by 2 cm.	Yes	No	Left quadriceps tendon	Local excision	No recurrence
56	F	60	.....	1 by 1 cm.	No	No	Proximal phalanx of left index finger	Local excision	Apparently no recurrence
57	F	52	2 years	5 by 3 by 2.5 cm.	Yes	No	Right peroneal tendon sheaths; erosion of fibula	Local excision	No recurrence after 6 weeks
58	F	34	6 months	1 by 0.7 cm.	....	No	Extensor surface of distal joint of right little finger	Local excision	Recurred 4 months later; no recurrence after second excision
59	F	38	10 years	.....	....	No	Dorsum of right foot	Local excision	No recurrence
60	F	47	2 years	1 by 1 cm.	Yes	Yes	Lateral surface of proximal phalanx of right middle finger	Local excision	No recurrence
61	M	27	3 years	0.5 by 0.5 cm.	Yes	No	Extensor surface of middle joint of right little finger	Local excision	No recurrence
62	F	28	7 years	.....	Yes	No	Dorsum of right foot and ankle (recurrent)	Local partial excision and roentgen therapy	Still present
63	F	39	10 years	3 by 3 cm.	No	No	Both achilles tendons; medial aspect of distal phalanx of right index finger; lateral aspect of proximal phalanx of right middle finger; medial aspect of proximal phalanx of both thumbs	Local excision	?
64	F	42	28 years	3 by 2 cm.	No	No	Both achilles tendons; left plantar fascia	Local excision	Died of septicemia
65	F	41	6 years	1 by 1 cm. largest	No	Yes	Right achilles tendon; distal phalanx of right index of right thumb	Local excision and roentgen therapy	?
66	F	40	15 years	5 by 3 cm.; 1 by 1 cm.; 2 by 2 cm.	No	Yes	Both achilles tendons; right and left extensor tendon sheaths over third metacarpal bone; both triceps tendon sheaths	Local excision from achilles tendons and fingers	No recurrence
67	M	45	4 years	2.5 by 2.5 cm.	Yes	No	Tendon sheath at insertion on right radius; erosion of radius	Local excision	No recurrence 1 year after
68	F	68	6 months	3 by 2 cm.	No	No	Dorsum of left wrist	Local excision	No recurrence
69	F	52	1 year	1.5 by 1.5 cm.	Yes	Yes	Extensor surface of distal joint of right ring finger	Local excision	No recurrence after 2½ mos.
70	F	36	20 years	13 by 8 cm.	Yes	No	Diffuse, synovial membrane of right knee	Synovectomy and roentgen therapy	No recurrence

fell in the fifth decade; the sixth decade was next with 14; the fourth followed with 12; there were 10 in the third, 9 in the seventh and 3 in the second. None were in the first decade.

The occupation of 69 of the 70 patients was recorded. Thirty-nine were housewives, who are notorious for minor accidents and injuries that frequently go unnoticed and untreated. The remaining 30 were engaged in various occupations, ranging from sedentary clerks to farmers, laborers in steel and other persons in hazardous positions. Practically all were engaged in vocations that more or less constantly exposed them to the dangers of everyday mild to severe trauma, from the constant pressure of a pencil against the fingers in writing to the handling of heavy and complicated machinery, the havoc of which is seen every day in the dispensaries and outpatient departments.

The weight of each patient was determined. It was found that in 37, or 53 per cent of cases, there was a record of obesity, with an average of about 24 pounds (10.9 kg.) overweight per patient.

Thirty-one, or 44 per cent, of the patients had a specific history of trauma; 14, or 20 per cent, had arthritis in the involved extremity, and 6 had a history of both infection and trauma, making a total of 39, or 56 per cent, with either an infectious or a traumatic background.

In 62 cases there was a record of the duration of the tumor, the average being six years and one month. The longest duration was twenty-eight years; there were 2 patients, 1 of whom had a tumor of the left middle finger and 1 who had xanthomas of the right and left achilles tendons and the left plantar fascia. The shortest duration was one month; the growth was a tumor of the right middle finger.

In 70 patients observed there were 88 tumors. Sixty-five patients had 82 tumors of the tendon sheaths, and 5 had 6 tumors of the synovial membranes. There were 4 patients with 2 tumors each and 2 with 3 tumors each. Two patients had 6 each. Sixty-four of these lesions were located on the upper extremity and 24 on the lower. Of those occurring on the upper extremity, 54 were on the fingers, 6 on the hands, 3 about the elbow and 1 on the wrist. In the lower extremity, 15 were located in the tendon sheaths about the foot and ankle, 2 about the knee, 1 on a toe and 6 in the synovial membrane of the knee. Sixty were on the right side and 28 on the left. The flexor surface was involved 28 times, the extensor 37 times, the medial 3 times, the lateral 4 times and the flexor and extensor twice. In 8 instances the surface was not indicated. Thirty-eight of the tumors involving the tendon sheaths of the fingers were on the right extremity, and 16 were on the left; 20 occurred on the flexor surface, 17 on the extensor, 4 on the lateral, 3 on the medial and 2 on the flexor and extensor. In 8 instances the surface was not indicated. The middle finger was the most common site, with 19

tumors; the index was next with 12, and this was followed by the thumb and ring fingers with 8 each and by the little finger with 7. In 17 instances the tumor was situated on a level with the distal phalanx; in 15 it was opposite the proximal phalanx; in 9 it was opposite the middle phalanx; in 6 it was over the distal joint; in 5 it was over the middle interphalangeal joint, and in 1 the level was not recorded. The remaining tumors of the tendon sheaths were located as has been described.

The tumors of the synovial membrane were found in the knee, and only 1 was a real diffuse xanthoma. One was diffuse but limited to the suprapatellar pouch, and the remaining 4 were pedunculated. The right knee was involved twice, with 2 tumors, the left 3 times, with 4 tumors.

Twelve of the patients on their first visit to the clinic presented a recurrent tumor. In 10 there had been only one recurrence; in 2 there had been two recurrences. The previous operation had been done from six days to eleven years before the patient arrived here. In 7 patients the interval between operation and recurrence was known, the average approximating one year.

The history elicited was usually the same, the patients complaining of a slowly growing, painless mass, seldom causing any disability except when the size was sufficient to produce mechanical block of the motion of a joint. In some instances it was preceded by injury, but often no history of a definite injury could be elicited. Frequently the patient came for operation with the fear of a malignant lesion as his prime reason; in other instances treatment was sought only for cosmetic purposes. The fear of a malignant lesion in most cases was due to suspicions raised by the patient's family physician. In some cases biopsy had been done, with the usual diagnosis of sarcoma, and the physician had advised the patient to have the extremity amputated.

On physical examination the usual picture was that of a subcutaneous firm mass of varying size and shape, not tender on pressure and located in the vicinity of the tendon sheaths or on them (fig. 1). The overlying skin was unattached, but evidence of attachment to deeper structures was present. Even if it was evident that the mass was fastened to the sheath, motion of the tendon in the sheath was not hampered. There was never any ulceration of the skin or sign of local or general metastasis, and in only 1 case was there a record of local heat; this occurred in a tumor of the ankle seen during the past year that had been previously operated on and had received much local treatment subsequently. The signs and symptoms observed in the knee were those of any internal derangement of this joint.

The results of routine laboratory tests were all essentially negative with regard to this condition. In 12 cases the values for total blood lipoids were determined. In 10 of these the values for blood cholesterol,

cholesterol esters, lecithin and total fatty acids were also determined, and in 2 the values for cholesterol esters and lecithin were not recorded. In 1 case of the 10 a second determination was carried out after two months of a cholesterol-free diet. The normal for these substances as determined at the Mayo Clinic is given in table 2. Using the ratio of the mean normal value of cholesterol and cholesterol esters as a standard (1.4), we determined the ratio of these values for each patient to see whether there was any variation. In 6 patients there was an absolute elevation of the value for total blood lipoids. In 10 cases the ratio of cholesterol to cholesterol esters was determined; in 5 there was an increase in the ratio and in 3 a decrease, and in 2 the ratio was normal.

Fig. 1.—Xanthoma involving the extensor tendon sheath of the right index finger.

In all but 2 cases, then, there was either an elevation of the absolute values or a disturbance in the cholesterol–cholesterol ester ratio. It is interesting to note in the case of the patient who had been on a cholesterol-free diet that although the absolute values had returned to normal the ratio of cholesterol to cholesterol esters remained the same (table 2).

Sixty-nine of the 70 patients were treated surgically at the Mayo Clinic. One patient came here after operation had been completed at home, bringing with him the tissue that had been excised. After the diagnosis had been established, the patient was given a course of roentgen treatment. Sixty-seven patients were treated by local excision alone, and 8 were given roentgen treatment in addition to local excision. This was done only when it was felt that all of the tumor had not been

or could not be completely removed. In 1 case of diffuse xanthoma of the knee, a synovectomy was done. In 9 a recurrence is known to have taken place, and in 5 of these a second excision was carried out; in 1 of these the patient received, in addition, a course of roentgen treatment.

Most of the tumors were easily shelled out intact and without much damage to the surrounding tissues. In some instances (for example, case 62) in which the tumor was diffuse and infiltrating, complete removal was not possible, and in case 66 a marked involvement of the achilles tendons made it necessary to do a secondary plastic operation on the tendons. In nearly all cases excision was carried out with the region under local anesthesia and with a tourniquet.

TABLE 2.—*Blood Chemistry of Patients with Xanthoma*

Date	Case	Cholesterol	Cholesterol Ester	C : CE Ratio	Lecithin	Total Fatty Acids	Total Lipoids
Normal	..	160-200 Mg./100 cc.	110-145 Mg./100 cc.	1.38-1.45	200-250 Mg./100 cc.	335-350 Mg./100 cc.	500-550 Mg./100 cc.
Mean	..	180	127.5	1.41	225	342.5	525
6/27/38	38	321	208	1.54	278	368	689
2/ 1/38	49	175	136	1.29	200	265	440
6/ 4/38	51	126	89	1.42	172	251	377
6/20/38	52	168	100	1.68	208	211	379
1/18/38	55	139	116	1.20	192	242	381
6/21/38	58	238	181	1.31	218	372	610
6/ 7/38	59	333	214	1.56	315	363	696
6/20/38	62	231	141	1.64	198	289	520
8/ 9/38	62	170	104	1.63	185	247	417
5/ 2/38	65	206	132	1.56	208	394	600
3/19/36	66	476	...	....	...	540	1,016
4/26/38	67	222	...	....	...	306	528
7/26/38	69	248	174	1.43	250	495	743

The size of the excised tumors was determined in 74 instances. Of 56 tumors of the upper extremity the average size was 1.5 by 1 cm. Of 18 tumors involving the lower extremity the average size was 5.5 by 4 cm. The average size for the entire group was 2.5 by 2 cm.

Grossly these tumors appeared as round or ovoid, practically always lobulated, well encapsulated solid masses, moderately firm to quite firm, varying from grayish yellow through yellowish brown to reddish brown. A tumor might show all these colors, or it might show only one. Some, particularly those about the ankle, showed no limiting capsule, and some were of a rather infiltrating nature. This, however, was the exception and not the rule. They cut with increased resistance, depending on the relative amount of fibrous tissue, cellular tissue and fat. The cut surface revealed the same varieties of color as did the outer surface, and in addition each lobule was outlined by whitish strands of fibrous tissue extending inward from the capsule in an interlacing manner (fig. 2).

Microscopically, their appearance varied (fig. 3). Certain definite characteristics, however, were nearly always observed; for example, foam cells, foreign body giant cells, pigment and fat. The cellular and fibrous elements were always the same, but in some the fibrous tissue predominated and in others the cellular constituents were foremost.

Fig. 2.—Gross appearance of a diffuse xanthoma removed from the suprapatellar pouch.

In some the fibrous elements were predominant in one section, and in the next the cellular elements might make up the greater part of the section. The fibrous tissue varied from fine strands of tissue to heavier and denser portions. In some an osteoid-appearing tissue was present, but closer examination revealed very dense fibrous tissue.

The type cell of the stroma was in all instances the same (fig. 4). It was polyhedral, oval or round, containing one nucleus that was

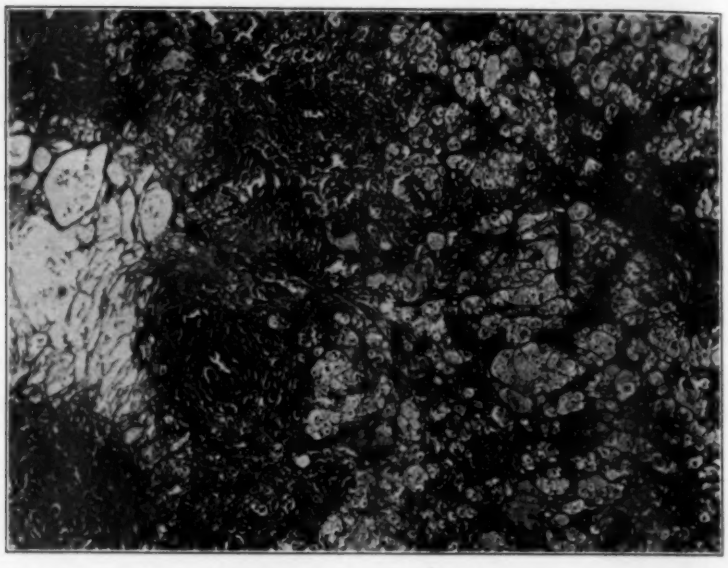

Fig. 3.—Xanthoma showing large numbers of foam cells in the right side of section and cholesterol clefts in the left side. Fibrous and cellular stroma and several foreign body giant cells are present. × 60.

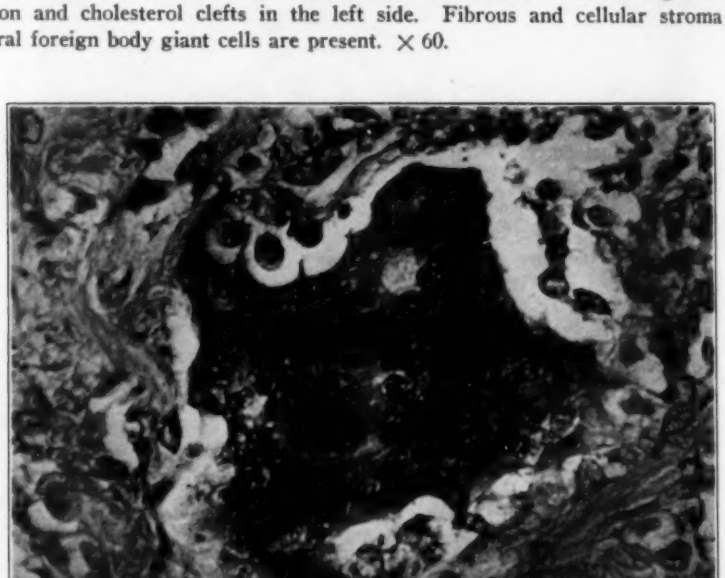

Fig. 4.—Xanthoma, showing the shape and structure of a foreign body giant cell, with characteristic cytoplasm and many endothelium-like nuclei. The surrounding tissue shows typical endothelium-like stroma cells with their pale-staining nuclei and prominent nucleoli. × 440.

usually large and either round or oval. Each nucleus stained lightly and contained one and sometimes two darkly stained nucleoli. The cytoplasm of these cells took the eosin stain faintly and was rather homogeneous and slightly granular. These cells looked not unlike endothelial cells and were arranged usually in solid masses, separated only by the interlacing strands of fibrous tissue. Some spindle cells were present in small numbers, and very few polymorphonuclear leukocytes were observed in any one section. Mitotic figures were seen only on rare occasions and in only 12 of the tumors. The type cell did not show the polymorphism, polychromatophilia or atypical mitosis characteristic of malignant tissue. No tumor giant cells were found in any one section.

Foam cells were found in all but 8 tumors (fig. 3). These cells were of varying size and shape; their cytoplasm had a granular, foamy appearance, and the nuclei were smaller than those of the type cell, having a shrunken, pyknotic appearance. There rarely was more than one nucleus, and it took a heavier stain than did the type cell. The foam cells were found in varying amounts, from tiny groups to collections so large that they made up practically the entire cellular content of the tumor. In some sections they were seen only on the periphery; in others they were scattered throughout the tumor.

Giant cells of the foreign body type were found in all but 1 (fig. 4). They varied in size and shape, but a rectangular cell seemed to predominate. Their nuclear content varied from two or three per cell up to two hundred or more. These cells were found in large numbers in close approximation to hemorrhagic regions, pigment and regions showing cholesterol crystals. They were numerous in some sections, showing as many as fifty-two per low power field. In some sections only a few could be found in the entire lesion. Their cytoplasm was pink and homogeneous, with nuclei that resembled those of the cells of the stroma; in other words, they looked like endothelial cells. Each giant cell was usually seen lying in a clear space, but in some cases they were in direct apposition to the stroma of the tumor.

In all the sections except one the presence of hemosiderin pigment was revealed by the iron stain method. The pigment content varied from small amounts to amounts sufficient to fill the section heavily throughout. It was chiefly intracellular; the stroma cells in many instances revealed large deposits. Innumerable giant cells displayed intracellular pigment, and in nearly every section in which foam cells were present, from a few to the entire group, intracellular pigment was seen, and in some these cells were heavily laden with pigment (fig. 5).

Every section studied displayed the presence of fat when stained by the scarlet red method. The fat varied from very small amounts to amounts sufficient to load the section. It too was chiefly intracellular, and the largest amounts, of course, were within the foam cells. Some of the foreign body giant cells also showed some intracellular fat. Twenty-eight tumors displayed cholesterol crystals, seen principally in the foam cells (fig. 6). Ten tumors showed cholesterol clefts. Four sections showed both crystals and clefts; thus 34, or practically 50 per cent, revealed the presence of either cholesterol crystals or their clefts.

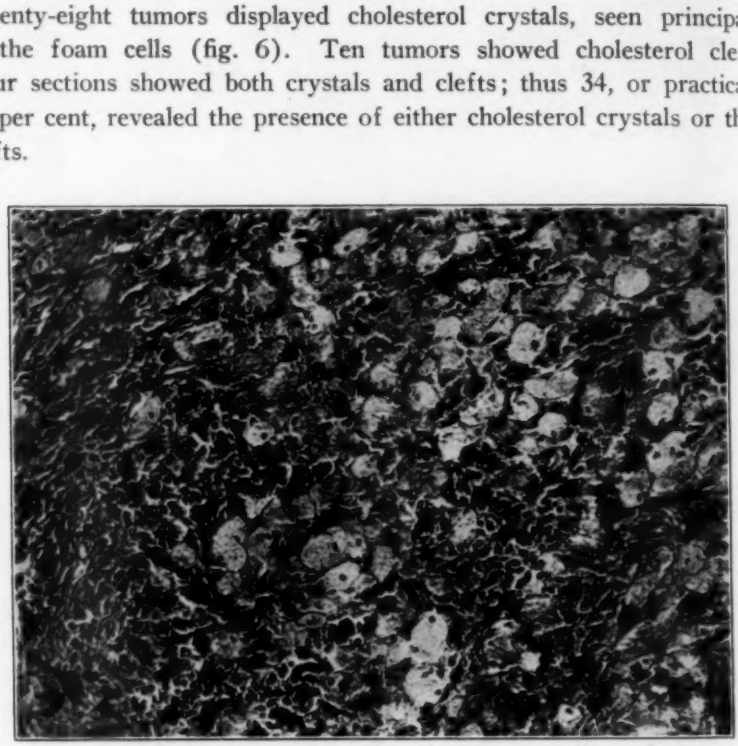

Fig. 5.—Xanthoma, showing the pigment content of the foam cells and the larger deposits in the stroma cells. × 200.

There was evidence of a good blood supply in all the tumors. Of course this varied a great deal, but in every one small blood vessels could be found about the periphery, and in some larger vessels were visualized. In a large number, in addition to the peripherally arranged vessels, numerous small blood vessels and sinuses were distributed throughout. Innumerable sections showed scattered hemorrhagic regions.

An attempt was made to grade these tumors according to their relative cellular and fibrous content, foam cell content, giant cell content, fat content and pigment content. A tumor was called grade 4 if it showed more than 75 per cent cells or more than 75 per cent fibrinous tissue; for example, grade 4 cellular. If the cellular or fibrous content made up 50 to 75 per cent the tumor was designated

as grade 3. Of course, if a tumor is grade 3 cellular, it must be grade 1 fibrous and vice versa. When the tumor consisted of equal parts of cells and fibrous tissue it was called grade 2 fibrous and cellular. The tumors were graded also on a basis of percentage of foam cells, grade 1 being a tumor made up of 1 to 25 per cent foam cells; grade 2, 25 to 50 per cent; grade 3, 50 to 75 per cent, and grade 4, 75 to 100 per cent. They were graded as to fat content on a similar rating. The grade according to content of foreign body giant cells was figured on the following basis: Tumors in which there appeared only a few of these cells were designated as grade 1; those showing one to seventeen per low power field, as grade 2; those with eighteen to thirty-five

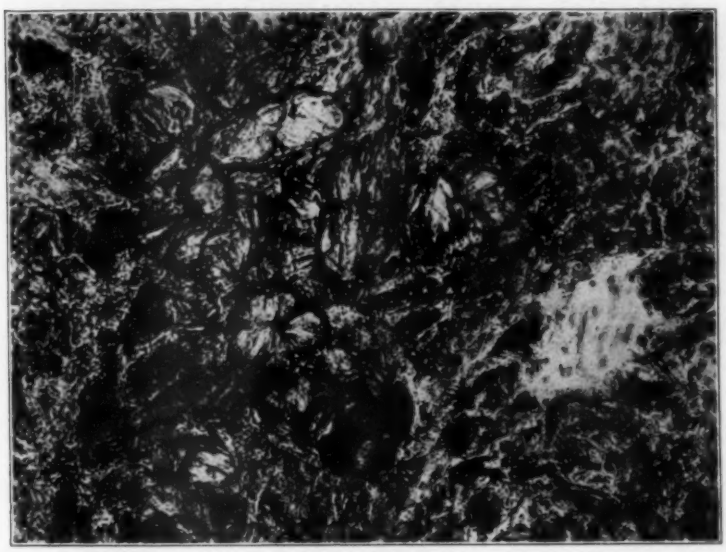

Fig. 6.—Xanthoma, showing foam cells containing intracellular fat and cholesterol crystals. Scarlet red stain; × 200.

per low power field, as grade 3, and those in which thirty-six to fifty-two per lower power field were seen, as grade 4. Grading according to the pigment content was decided by the following method: Sections showing small isolated amounts up to small amounts of pigment scattered throughout were designated as grade 1; sections showing small to moderate amounts scattered throughout, as grade 2; sections with moderate amounts throughout, as grade 3, and sections with large amounts throughout, as grade 4.

A summary of these gradings is given in table 3 and is self explanatory. Sixty-eight tumors were thus examined histologically and

graded, 5 of them being recurrent lesions. It is of interest to note that the recurrent tumors usually showed the same relative amounts of the various constituents as had the original tumor.

A chemical analysis of these tumors was possible in only 3 cases (table 4).

Follow-up studies were obtained on 61 patients. In 9 instances no record of the result was obtainable; in 7 of these treatment had been recent, and the interval since operation was too short to make the results of any value at this time. One patient died of septicemia after operation. In the entire group there were 9 recurrences, a total of 12 per cent. In 3 patients, although there was no recurrence at the site

TABLE 3.—*Summary of Constituents of Xanthomas*

Constituents	Absent	Grade 1	Grade 2	Grade 3	Grade 4	No Slide	Total
Cells	..	..	..	16	18	0	
Fibrous tissue	..	..	..	17	5	0	
Cells and fibrous tissue	..	..	12	..	..	0	68
Foam cells	8	40	9	5	6	0	68
Foreign body giant cells	1	13	45	6	3	0	68
Pigment	1	26	27	7	6	1	68
Fat	..	42	9	5	7	5	68

TABLE 4.—*Percentage Lipoid Content of Xanthomas*

Case	Cholesterol	Cholesterol Ester	Lecithin	Total Fatty Acids	Total Lipoids
38	...	...	...	...	2.87
51	3.0	2.6	2.9	4.0	7.0
69	0.66	...	0.86	1.74	2.4

of the previous operation, similar tumors appeared at other sites, and in all instances these new appearances took place on the fingers and on the palm.

REPORT OF CASES

A report of a few cases illustrating most of the typical findings in this class of tumor will now be presented.

CASE 32.—A housewife aged 50 was admitted to the Mayo Clinic on Sept. 4, 1933, complaining of a mass on the end of the right index finger of sixteen years' duration. Her family history and past medical history were irrelevant. The laboratory findings were essentially normal. The patient stated that the present tumor had appeared shortly after the finger had been caught in an electric wringer. Growth had been slow, and the tumor was painless and caused her no disability. On examination two firm, oval masses, the larger located on the extensor surface and the smaller on the flexor surface of the index finger, were found. Both were limited to the distal phalanx. There was no tenderness or local heat, and motion of the joint was not limited. On September 7 two growths were excised, a tumor

1 cm. in diameter, from the extensor surface, and a tumor 6 mm. in diameter, from the flexor surface. A letter received from the patient in September 1938 stated that there had been no recurrence of the tumor at the site of the previous operation but that similar masses had appeared on other fingers.

CASE 38.—A nun aged 49 was admitted to the Mayo Clinic on July 15, 1935, complaining of a painless mass on the end of the right middle finger. The family history and past medical history were irrelevant. The results of routine laboratory tests were negative. The patient related that at the age of 15 she had pinched the end of this finger severely in a pump handle. Five years before admission a small mass had appeared in this region and had since been slowly increasing in size. The patient was curious concerning the nature of this growth and for this reason and cosmetic reasons wished to have it removed. On examination a small, firm mass about the size of a pea was found on the extensor surface of the distal phalanx of the right middle finger, toward the ulnar side. There was no tenderness, local heat or interference with motion of the joint or of the tendon. On July 19 a round, yellowish, firm tumor 7 mm. in diameter was excised. The wound healed by primary intention, and the patient was dismissed.

On June 21, 1938, this patient returned with a similar mass at the site of the previous excision, which she stated had made its appearance about one year after the operation. There was some pain. The patient said that the tumor had been growing slowly. She stated that she was accustomed to doing a moderate amount of sewing, that she wore a thimble on this finger and that the thimble possibly irritated this region. The physical findings were similar to those recorded on her first visit. The values for blood lipoid were determined; that for cholesterol was 321 mg., that for cholesterol ester 208 mg., that for lecithin 278 mg., that for total fatty acids 368 mg. and that for total lipoids 689 mg. per hundred cubic centimeters of plasma. The cholesterol–cholesterol ester ratio was 1.54:1. On June 27 a second excision of a similar tumor was performed (fig. 7). The wound healed quickly, and the patient was put on a low cholesterol diet and dismissed. No further record of this patient has been available.

CASE 15.—A farmer aged 56 came to the Mayo Clinic on Dec. 4, 1923, complaining of swelling, stiffness, soreness and a burning sensation of the right ankle. His past medical history was irrelevant. He said that his mother had had a similar mass for forty years. He stated that thirty-five years previously his right foot and ankle had been caught between two logs and severely bruised. There were pain and discoloration of the foot and ankle for one month, but no more trouble until six years previously, when he noticed that this ankle was larger than the other. There was no pain or tenderness at this time, and function was not impaired. The ankle slowly increased in size and became progressively weaker; he noticed the weakness particularly after too much use. After prolonged rest and in the morning it was stiff and sore, and recently a burning sensation had appeared in the overlying skin. On examination a fairly firm soft tissue mass of moderate size was found over the medial and lateral surface of the ankle, and this appeared to be connected posteriorly to the posterior tibial tendon. There was only slight tenderness, and there was no local heat. On December 14 the tumor was excised. It originated apparently from the posterior tibial tendon behind the internal malleolus and extended behind the tendons and nerves to the fibula, causing the achilles tendon to bulge for about 8 to 9 inches (20 to 22 cm.). It involved the plantar structures, extending well down into the ball of the foot, and spread over the external malleolus,

forming a tumor here connected with the peroneal tendons. The posterior tibial nerve was completely surrounded by the tumor mass and had to be dissected free. The tumor was removed en masse (fig. 8). There were no postoperative complications, and convalescence was uneventful. The patient was dismissed in good condition.

On Oct. 24, 1927, he returned, stating that three and one-half months previously a mass had appeared over the external malleolus and had grown slowly toward the heel. A smaller mass had appeared behind the internal malleolus. He stated that he had sharp pain in the ankle at night after overuse. On examination a mass was palpable over the external malleolus and a smaller one posterior to the internal malleolus. There was limitation of motion of the ankle in all directions. On October 28 a second operation was performed. At this time the tumor was found

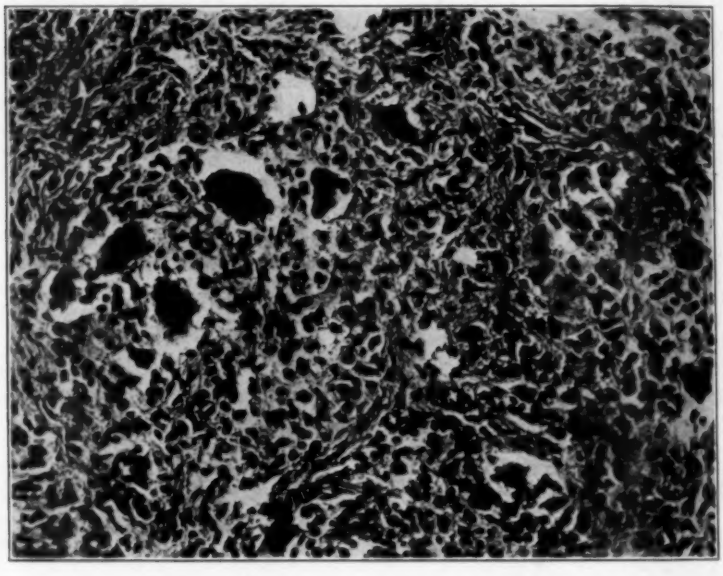

Fig. 7 (case 38).—Xanthoma of the tendon sheath of the finger, showing the interlacing strands of fibrous tissue separating the typical endothelium-like stroma cells and several foreign body giant cells. × 200.

to have extended into and destroyed the tibiotarsal joint capsule on its anterior and lateral aspects and had extended up the peroneal tendons and across the front of and up along the inner side of the foot. It was impossible to excise the tumor completely. On November 11 and December 2 roentgen treatments were given. Convalescence was uneventful, and the patient was dismissed. A letter received from him in June 1928 described some pain and swelling of the ankle but did not say whether the growth was increasing. No further word has been received.

Case 51.—A student aged 19 was admitted to the Mayo Clinic on May 31, 1938, complaining of a painful knee on weight bearing. His past medical and family history were irrelevant. He stated that three years previously he had twisted his

knee several times while playing football and that during the past two years he had had attacks of pain in the knee after any twisting of the joint and on kneeling. There was no locking. A cast had been applied four weeks prior to admission and was still on when he arrived here. On physical examination there was grade 1 atrophy of the quadriceps muscle on a basis of 1 to 4. Flexion was limited to 80 degrees; there was no instability, and on the medial border of the patella a loose body could be palpated and rolled under the finger. The concentration of blood lipoids at this time was as follows: cholesterol, 126 mg.; cholesterol ester, 89 mg.; lecithin, 172 mg.; total fatty acids, 251 mg., and total lipoids, 377 mg. per hundred cubic centimeters of plasma. The cholesterol–cholesterol ester ratio was 1.41 : 1.

On June 4 the right knee was explored. When the synovial membrane was opened, the palpable nodule, which was about the size of a lima bean, was found

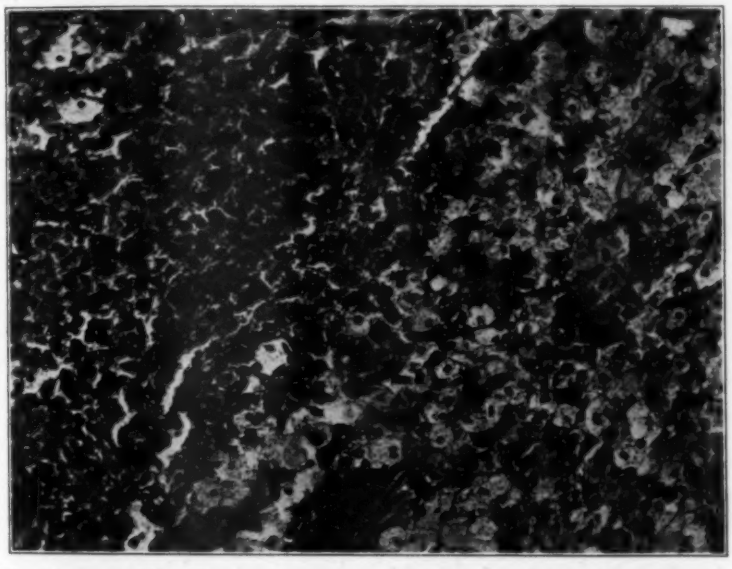

Fig. 8 (case 15).—Xanthoma of the ankle, showing the typical cell and foam cells. × 200.

attached to the synovial membrane on the medial side and hanging into the joint space. Osteochondritis dissecans of the medial condyle of the femur was present. The semilunar cartilages were not involved. The synovial membrane was somewhat thickened, and there were numerous small yellowish spots on its surface. The tumor was analyzed chemically, and the following values were obtained: cholesterol, 3 per cent; cholesterol ester, 2.6 per cent; lecithin, 2.9 per cent; fatty acids, 4 per cent, and total lipoids, 7 per cent. The wound healed by primary intention, and recent word from the patient is that he is steadily improving.

Case 70.—A woman aged 36 was admitted to the Mayo Clinic on Jan. 4, 1937, complaining of pain and swelling of the right knee of several years' duration. The family history, past medical history and laboratory findings were all noncontributory. This patient had a long history of repeated trauma. In 1916 or 1917, while running

hard and attempting to jump a wire fence, her toe caught in the wire and she fell with all her weight on the right knee. This accident was followed by moderate soreness and stiffness in the knee for about a week, but she was able to get about. One year later the knee was struck a terrific blow by an ice hockey stick. This was followed by some stiffness, soreness and swelling for a few days.

The patient had no further trouble until August 1929. At this time she noticed a soft, painless lump about the size of a walnut on the lateral aspect of the knee, just below and lateral to the inferior pole of the patella. The mass was movable, and on flexion of the knee it became larger and "rode up" higher on the knee. Within about two weeks it increased to the size of a hen's egg and became hard. Light therapy was used, and a tight elastic bandage was worn for two weeks.

The patient was free of symptoms until March 1930. At this time, on stepping down from a curb, the knee was sharply twisted internally, the leg being

Fig. 9 (case 70).—*A*, lateral roentgenogram of a knee containing a diffuse xanthoma of the synovial membrane; *B*, anteroposterior roentgenogram of the same knee.

stationary. The patient experienced a slight twinge of pain and a "giving way" sensation but was able to walk with only a slight limp. She went to a physician at this time, and with a diagnosis of dislocated cartilage the knee was manipulated. During all this time the mass on the outer side of the knee was increasing in size.

In March 1931, while the patient was getting off a streetcar, the knee was again twisted, and she fell to the street. This accident caused severe pain and marked swelling, the knee reaching its maximal size (about twice normal) within one hour. The patient had at this time a burning sensation in the knee, which felt hot to the touch. Weight bearing produced excruciating pain, and the patient was required to remain in bed for several days. Pain and stiffness disappeared in about two weeks, but swelling never disappeared. About one month later a similar attack was brought about during dancing, and at this time a definite clicking sound was perceptible in the knee. Symptoms were again marked, requiring rest

in bed for several days. The knee returned to normal (except for swelling) in about two weeks. The next year there were two more episodes of slipping, with the same symptoms. In 1932, after a treatment by a masseuse, she had an exacerbation of symptoms requiring rest in bed, this time for two weeks. After this she constantly wore an elastic knee cap, and for the next two years she had this "slipping out" of the knee on an average of about every two to three months. The mass on the lateral side of the joint reached its maximal size (that of a large hen's egg) in 1934 and by this time had attained the hardness of a rock. In August 1936 another attack was precipitated by wearing high-heeled shoes, and in November of the same year an attack occurred spontaneously. From that time on the patient had only slight twinges of pain in the knee, and there were no more

Fig. 10 (case 70).—Gross appearance of synovial membrane removed for a diffuse xanthoma of this structure. Note the deeply pigmented villi.

slipping episodes. She always had full range of motion except during these attacks, and there never had been any locking.

On examination the right knee was 1.5 cm. larger in diameter than the left (fig. 9). There was marked crepitation in the joint on motion. A thickened, fibrous mass was palpable lateral to the patella. There were apparent thickening of the synovial membrane and evidence of fluid in the joint. The palpable mass slipped in and out of the joint on flexion and extension. There was no tenderness or local increase in temperature. On Feb. 17, 1937, with the knee under a tourniquet, a short incision was made along the medial side of the patella and the patellar tendon. When the synovial membrane was opened, some brownish fluid escaped, some of which was sent for culture and was later reported sterile. A nodule the size of a large bean appeared in the wound immediately it was opened. The surrounding membrane was brownish and there were long, stringy villi. The whole

membrane was thickened and had the same stringy villi. The cartilages on the surface of the joint were slightly but not completely eroded. The semilunar cartilages appeared to be in good condition. A complete synovectomy was performed (figs. 10 and 11). A cast was applied from ankle to groin. Ten days later the cast was removed, and the patient began passive motion with the aid of an arthroplasty splint. On March 1 one roentgen treatment was given. Finally, on March 16, owing to poor progress in attaining motion, the knee was manipulated, with the patient under anesthesia. From then on motion gradually increased, and the patient was dismissed on March 23 with motion in the knee slowly improving. This patient was seen at the Mayo Clinic in May 1938, with no evidence of any recurrence. She said she had had trouble limbering up the knee, but at this time, there was full range of motion. There was no evidence of synovial thickening.

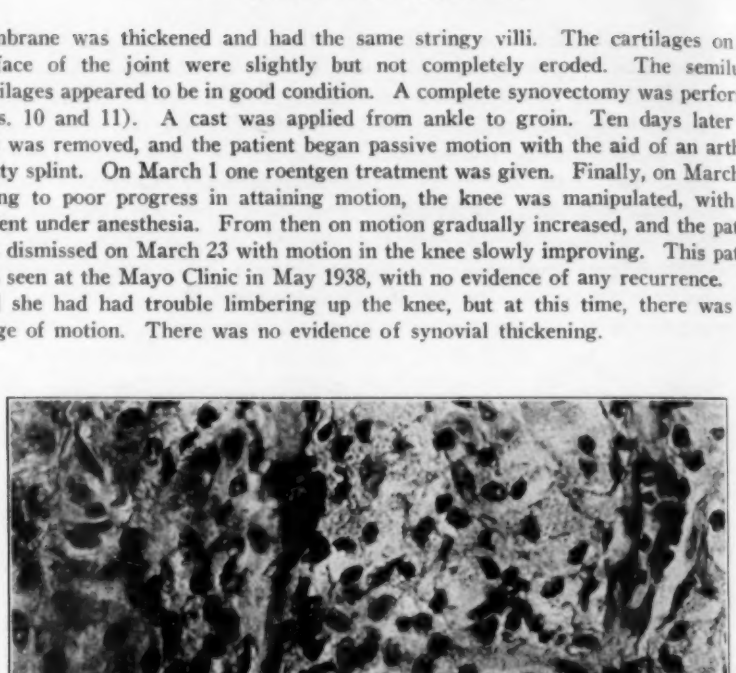

Fig. 11 (case 70).—Xanthoma of the synovial membrane of the knee, showing large numbers of foam cells in the left half of the section and the typical endothelium-like cells of the stroma in the right half. × 400.

COMMENT

As has been brought out in the foregoing sections, xanthoma is a slowly growing, painless tumor, usually taking years to develop (five years and one month on the average in the cases reviewed in the literature and five and a half years in our own cases). It causes no disability except when it becomes large enough to interefere mechanically with adequate motion of the joints or proper function of the extremities. It varies in size and shape but in most cases is a firm round or oval lesion, averaging from 2.5 to 3 by 2 cm. It is slightly smaller when it occurs on the hands and finger than when it occurs on the feet

and ankles. It occurs on the upper extremity two to three times as often as on the lower, involving the finger most frequently. It is most common on the index and middle fingers, as is shown by both series of cases. In the cases collected from the literature the flexor surface was involved 102 times and the extensor surface 41 times. In our group of cases the flexor surface was involved 28 times and the extensor surface 37 times. In the combined experiences the flexor surface was involved 130 times and the extensor surface 78 times. Although numerous writers have said that these tumors nearly always occur on the flexor surface, they certainly must have based their conclusions on only a few cases, as these figures show. It is conceivable that the tumors probably arise most often on the flexor surface, for this is the surface that is most frequently the site of trauma; however, we must conclude that both surfaces are affected, and the surface on which the growth occurs cannot be used as a criterion for diagnosis.

Etiology.—Age and Sex: The average age of the patients in the series collected from the literature was 37.5 years, as compared with an average of 44 years in our own group of patients. The greatest number fell in the third, fourth and fifth decades. In those patients seen at the Mayo Clinic the largest number fell in the fourth, fifth and sixth decades. In the cases reviewed here there were 71 per cent women and 29 per cent men, while in those in the literature there were only 55 per cent women and 46 per cent men. From these figures we can conclude that the two sexes are about evenly involved, the female predominating a little. We can also conclude that the average age is about 40 years; however, no age is immune, for tumors in a patient aged 82 have been reported by Malherbe,[11] and Garrett [43] spoke of a congenital tumor.

Heredity: The genetic factor plays a doubtful part, for we were able to find only 1 case in which it was present. The mother of the patient, treated here, had had a similar growth for forty years. Thannhauser and Magendantz [78] reported the cases of 2 patients who were brother and sister. It appears, however, that this phase of the subject has been woefully neglected, and perhaps if the antecedents of these patients could have been thoroughly investigated, some factor linking the two together would have been discovered in many more cases. However, at present and from a statistical standpoint, this factor in the causation of this growth must be discarded.

Occupation: There is little help from the literature on this score, for the occupation was listed too infrequently to be of value, and when it was mentioned most of the writers disagreed on the part played by it. Of the patients observed here, over 50 per cent were housewives

and persons leading active lives, so perhaps occupation does play a larger part than most students of xanthoma are wont to believe.

Trauma: Many authors, such as Tourneux,[13] Beekman,[8] Broders,[38] Buxton,[42] Janik,[50] Mason and Woolston,[49] King,[9] Razemon and Bizard,[92] Young and Harris,[96] Grant and Stewart,[34] Kurtz,[54] and Garrett,[42] have stated the belief that trauma plays an important role in the production of these growths. The records in the literature are scanty. In less than half of the cases collected from it, a history of trauma was found in 19 per cent; thus, probably if there had been a record of the absence or presence of injury in all cases the figures would probably have reached about 40 per cent, for of the cases collected here such a history was obtained in 44 per cent. The more frequent occurrence of the tumors on the fingers and hands than on the forearm and arm and on the feet and ankles than on the rest of the extremity seems to substantiate this view. The probability is that the trauma responsible for the appearance of these growths is so mild, chronic or constant that the patient hesitates to provide the information, feeling it to be of little importance, and the examiner in most instances fails to elicit such data, for the same reason. In the same manner, infection in the extremity can be ascribed as a factor. We were able to find evidence of such infection in 23 per cent of our cases. Therefore, it is felt that trauma principally, and possibly infection, or both are the most important secondary factors in the production of these tumors; not severe, maiming trauma, but mild, unnoticeable constant injury concomitant with the daily routine of life. Zumtobel[70] and others have denied that infection or trauma plays a part in this condition; however, in the face of opposition we remain steadfast in our belief.

Lipoid Metabolism in the Production of Xanthoma: Here again a great controversy arises as to the importance of alterations in lipoid metobolism in the causation of these tumors.[97] Let us first consider what is known about this subject up to the present time. There are three main groups of lipoids usually recognized in the blood that play a part in the metabolism of the body functions: first, lipoids in the strict sense, consisting of the nitrogenous phosphatides and cerebrosides, the phosphatides being the so-called lecithins, cephalins and sphingomyelins. They are practically never found in the pure state but occur in connection with one another or with members of the rest of the group. They are found principally in the brain and adrenal cortex and are part of the fatty substances found in the organs of inter-

96. Young, F., and Harris, C. T.: Complete Excision and Reconstruction of Both Achilles Tendons for Giant Cell Xanthoma, Surg., Gynec. & Obst. **61**:662-669 (Nov.) 1935.

97. Geschickter, C. F.: Lipoid Tumors, Am. J. Cancer **21**:617-641 (July) 1934.

nal secretion. The second group includes cholesterol and its fatty acid esters, chiefly found in the adrenal cortex and the glands of internal secretion. The third group includes the glycerin esters, or neutral fats, which form the bulk of the fatty tissues of the body (Aschoff;[98] Thannhauser and Magendantz;[78] Gaines[99]). Cholesterol, a hydrophilic colloid, was first isolated from gallstones by Conradi[100] in 1775. It is the chief member of the sterols, with the formula $C_{27}H_{45}OH$, is an essential constituent of all living cells and is obtained chiefly from food but in part, according to Ingram,[101] it may be synthesized in the body (Bodansky;[102] Campbell;[103] Stewart[104]). Its connection with xanthomatous changes was first pointed out by Pinkus and Pick[105] in 1908, and again in 1910 by Chauffard.[106]

All these constituents are insoluble in water; thus they exist in the serum not in a dissolved form but in that of a finely dispersed stable emulsion. In order for these constituents to carry out their normal functions in the body their physical state must be maintained at all times. This stability of the emulsion is maintained by the proportions between the various lipoids and the albumin of the serum. If the concentration of any one element or of several elements is altered, the result, according to the laws of colloid chemistry, is a disturbance of the stable aqueous emulsion; the particles become coarser, the emulsion separates and finally, when conditions are suitable, there is a precipitation of one or all of the individual constituents and various lesions

98. Aschoff, L.: Lectures on Pathology, New York, Paul B. Hoeber, 1924, pp. 1-33.

99. Gaines, M. T.: Xanthomatosis, with Report of Case, South. M. J. **26**: 489-496 (June) 1933.

100. Cited by Bodansky.[102]

101. Ingram, J. T.: Xanthomatosis Cutis and Hypercholesterolaemia, Brit. J. Dermat. **39**:335-346 (Aug.-Sept.) 1927.

102. Bodansky, M.: Introduction to Physiological Chemistry, ed. 2, New York, J. Wiley & Sons, Inc., 1930, pp. 83-84.

103. Campbell, J. M. H.: Critical Review: Cholesterol in Health and Disease, Quart. J. Med. **18**:393-422 (July) 1925.

104. Stewart, M. J.: On the Cellular Reactions Induced by Local Deposits of Cholesterin in the Tissues, J. Path. & Bact. **19**:305-314, 1914-1915.

105. Cited by Rowland, R. S.: Anomalies of Lipid Metabolism (Constitutional Pathologic Lipidoses), in Christian, H. A.: Oxford Medicine, New York, Oxford University Press, 1931, vol. 4, pt. 1, pp. 214(3)-214(109); Xanthomatosis and the Reticulo-Endothelial System: Correlation of an Unidentified Group of Cases Described as Defects in Membranous Bones, Exophthalmos and Diabetes Insipidus (Christian's Syndrome), Arch. Int. Med. **42**:611-674 (Nov.) 1928.

106. Chauffard, cited by McWhorter, J. E., and Weeks, C.: Multiple Xanthoma of the Tendons, Surg., Gynec. & Obst. **40**:199-206 (Feb.) 1925.

or diseases result, depending on the lipoid that is precipitated (Bloch).[107] How the body maintains this constant level is not known, but Bloch,[107] Campbell,[108] McMeans[108] and many others concluded that the liver is the seat of control of this mechanism. McMeans concluded that the adrenals also play an important part.

The determination of any one constituent is not of much value; all must be determined quantitatively, and, above all, the ratio of the free and bound cholesterol must be known, for a disturbance in this ratio will alter the state of the stable emulsion and allow precipitation of one or more of the several blood lipoids. Bloch,[107] Schaaf and Werner[109] and Tate[110] stated that it is of more importance to know the relative values of the lipoid content than to know the absolute values and that hypercholesteremia does not mean much if all the other elements are proportionally increased but that, if the ratio between the various constituents is altered, the factors necessary for the precipitation of the substances into the tissues are present. It will be noted that of our cases in which the values for blood lipoids were determined, just such an alteration was observed in all but 2.

In the various diseases which result from disturbed lipoid metabolism, the lipoid that is deposited differs in each case. For example, in Gaucher's disease the cerebrosides are deposited; in Niemann-Pick's disease the phosphatides are deposited, and in Christian's syndrome and in the solitary and multiple xanthomas the lipoids deposited are cholesterol and cholesterol esters (Gaines;[99] Rowland[111]). In 50 per cent of our cases evidence of the presence of cholesterol deposits was observed. What, then, is the mechanism of production of hypercholesteremia? Chauffard[106] stated the belief that there are two types besides the increased cholesterol of alimentary origin: one is the result of disturbed hepatic function resulting in retention of cholesterol and is passive; the other is the result of endocrine secretion and is active. Others have concluded that the hypercholesteremia is entirely of alimentary origin. Schönheimer[109] came to the conclusion that the patient

107. Bloch, B.: Metabolism, Endocrine Glands and Skin-Diseases, with Special Reference to Acne Vulgaris and Xanthoma, Brit. J. Dermat. **43**:61-87 (Feb.) 1931.

108. McMeans, J. W.: Tissue Reactions in Experimental Hypercholesterinemia, J. M. Research **33**:481-491 (Jan.) 1916.

109. Cited by Gruenfeld and Seelig.[7]

110. Tate, B. C.: Cutaneous Xanthomata Associated with Intermittent Diabetes Insipidus (High Blood-Fat and Normal Blood-Cholesterol), Proc. Roy. Soc. Med. **26**:1546, 1933.

111. Rowland, R. S.: Anomalies of Lipid Metabolism (Constitutional Pathologic Lipidoses), in Christian, H. A.: Oxford Medicine, New York, Oxford University Press, 1931, vol. 4, pt. 1, pp. 214(3)-214(109).

may be able to absorb cholesterol but unable to excrete it and that this condition results in hypercholesteremia. Present day evidence, in spite of repeated experiments by many investigators, fails to place the cause of the increase or the alteration definitely in the ratio of the free and bound cholesterol. We are forced to conclude, however, that it does occur, and many writers have concluded that this is the primary factor in the production of these lesions, whether they are solitary or multiple. Among this group are Einaudi,[61] Ewing,[112] Pinkus and Pick,[105] Pringshein,[41] Weber,[45] Weil and Kirch,[3] Arning,[113] Bonn,[93] Kusnetzowsky,[114] Schmidt and Levy,[3] Dunn [115] and many others. Among authors who have opposed the hypothesis are Mason and Woolston,[49] Stewart and Flint,[36] Young and Harris [96] and Ragins.[10]

Although only a small group of personal cases are recorded in which the values for blood lipoids were studied, it is firmly believed that the alteration in lipoid metabolism, whether it be an absolute one or one of changes in the ratio of the relative constituents (principally the cholesterol–cholesterol ester ratio), is the primary etiologic factor in the production of these tumors and that trauma or infection (or both) in the involved areas is a secondary factor which is present in every case.

Pathologic Picture.—We have carefully recorded the pathologic picture of this tumor in a previous section of this paper, but we failed to explain the presence and origin of the various tissue elements. Let us, then, consider each separately.

The Foam Cell *(Schaumzelle)*, or Xanthoma Cell: This cell was accurately described by Chambard [116] and Török [116] over fifty years ago and at one time was suspected of being related to sebaceous gland cells and even of having a parasitic origin. Pinkus and Pick,[105] Aschoff [98] and Kawamura [116] observed that these cells possess phagocytic properties and came to the conclusion that they are reticuloendothelial cells infiltrated with fatlike substances. Anitschkow [116] definitely proved the identity of these cells with the histiocytes by showing their ability to pick up vital dyes, and Plewes [117] has demonstrated the presence of thorotrast in the foam cells. We too have demonstrated

112. Ewing, J.: Neoplastic Diseases: A Treatise on Tumors, ed. 3, Philadelphia, W. B. Saunders Company, 1928, p. 274.

113. Cited by Weber.[45]

114. Kusnetzowsky, N. J.: Ein Fall multipler xanthomatöser Granulome der Sehnen, Arch. f. klin. Chir. **124**:73-80, 1923; abstracted, Internat. Abstr. Surg. **37**:587-588 (Dec.) 1923.

115. Cited by Stewart and Flint.[36]

116. Cited by Rowland.[111]

117. Plewes, L. W.: Nature and Origin of the Xanthoma Cell, Arch. Path. **17**:177-186 (Feb.) 1934.

this characteristic by the presence of intracellular pigment in practically every tumor in which foam cells were present. Weber,[45] Broders,[38] Melicow,[118] Kolodny,[119] Gonzalez-Aguilar [58] and many others have considered them phagocytic cells, members of that class of cells known as the reticuloendothelial system. Pollitzer,[120] Mason and Woolston,[49] and Garrett [43] concluded that they are endothelial in origin. Broders [38] stated that they are lymphocytes that have taken on the special property of phagocytosis of fat particles.

What is meant by the reticuloendothelial system? Under this heading are grouped various cellular elements because of their common properties of phagocytosis, reaction to vital dyes and a general similarity of function; they include (1) the reticular cells of the splenic pulp, lymphatic tissues and bone marrow; (2) the endothelial cells of the liver capillaries, lymph sinuses, bone marrow, splenic sinuses, suprarenal and hypophysial capillaries, and (3) the phagocytic cells in the connective tissue, of which there are tissue histiocytes, splenocytes and blood histiocytes (Aschoff;[98] Sacks;[121] Rowland;[122] Oppenheimer and Fishberg).[123]

It is evident, then, that the origin of the foam cell from the reticuloendothelial system is established without any doubt.

Now that we have established the identity of this cell, the next question that arises is how the cholesterol happens to appear there. Aschoff [98] offered three possibilities: (1) by infiltration; (2) by fatty decomposition, and (3) by fatty transformation. He concluded, "that if fat transformation occurs," that is, transformation of the carbohydrates or protein reserve of cells into fat, "it must play only a very minor role and since fatty decomposition is either postmortem or necrobiotic, therefore pathological fat deposits can occur only in consequence of fatty infiltration which has its origin in the surrounding cell juices." Kawamura [116] and Anitschkow,[116] Rowland,[122] Pinkus and Pick,[103]

118. Melicow, M. M.: Xanthic Lesions: Report of Four Cases, Including Two of "Xanthomatosis" of the Kidney, J. A. M. A. **105**:768-774 (Sept. 7) 1935.

119. Kolodny, A.: Bone Sarcoma: The Primary Malignant Tumors of Bone and the Giant Cell Tumor, Surg., Gynec. & Obst. (supp. 1) **44**:1-214, 1927. Bone Sarcoma: The Primary Malignant Tumors of Bone and the Giant Cell Tumor, Chicago, Surgical Publishing Company, 1927, p. 186.

120. Pollitzer, S.: The Nature of the Xanthomata, New York State J. Med. **70**:73-80 (July 15) 1899.

121. Sacks, B.: The Reticulo-Endothelial System, Physiol. Rev. **6**:504-545 (July) 1926.

122. Rowland, R. S.: Xanthomatosis and the Reticulo-Endothelial System: Correlation of an Unidentified Group of Cases Described as Defects in Membranous Bones, Exophthalmos and Diabetes Insipidus (Christian's Syndrome), Arch. Int. Med. **42**:611-674 (Nov.) 1928. Footnote 111.

123. Oppenheimer, B. S., and Fishberg, A. M.: Lipemia and Reticulo-Endothelial Apparatus, Arch. Int. Med. **36**:667-681 (Nov.) 1925.

Lévy,[3] Oesterlin [124] and Smith [125] have expressed agreement with this hypothesis. Dewey,[126] Mason and Woolston,[49] and Virchow [8] concluded that this is brought about by a fatty tissue degeneration; Kaiserling and Orgler [8] expressed the opinion that the doubly refractile bodies originate within the foam cells. Weber,[45] Thannhauser and Magendantz [73] and Weidman [127] also concluded that these cells have the inherent property of being able to elaborate their fatty substance within the cellular body; that is, as Weber [45] expressed it, "it is due to lipoidophagic activity on the part of the cells themselves."

It appears that the general consensus favors the infiltration process, and in view of the marked phagocytic property of the foam cell, as has been pointed out before, we are inclined to agree with this idea.

The Giant Cell: Next we must consider the giant cell observed in this tumor. Mallory,[128] Dyke,[44] Hartman,[51] Weber,[45] Bellamy,[21] Broders [38] and Ragins [10] have concluded that this is a giant cell of the foreign body type, resulting from the fusion of endothelial cells. It has been called into action here as an aid in ridding the tumor of such irritant substances as particles of fat and pigment, and it is in regions in which such particles are present that the majority of these cells are found in the tumor. The morphologic similarity of the giant cell of these tumors to the osteoclasts has been pointed out by some. We believe not only that it is similar to the osteoclast but that the two cells are identical structures, displaying a difference only in their affinity for different foreign materials (Mallory;[128] Broders [38]). Touton [129] was the first to call attention to these giant cells seen in the xanthoma.

King,[9] Bellamy,[21] Garrett [43] and Weidman [130] concluded that too much attention has been paid in the past to the foam cells and the giant cells and too little to the type cell. They repeated that the foam cells and foreign body giant cells are not constant in the tumor and that

124. Oesterlin, E. J.: Xanthosarcoma, Ann. Surg. **91**:613-615 (April) 1930.

125. Smith, C.: The Histology and Nature of So-Called Foam-Cell Tumors with a Report of Four Cases of Endothelioma Xanthomatosum, Surg., Gynec. & Obst. **14**:551-557 (May) 1912.

126. Dewey, K.: Experimental Hypercholesterolemia, Arch. Int. Med. **17**:757-785 (June) 1916.

127. Weidman, F. D.: Xanthosarcoma of Cheek Succeeding Xanthosarcoma of the Forearm: Multiple Tumors Versus Metastasis, Arch. Surg. **34**:792-827 (May) 1937.

128. Mallory, F. B.: Giant Cell Sarcoma, J. M. Research **24**:463-467 (April) 1911.

129. Cited by Plewes.[117]

130. Weidman, F. D.: Studies in Hypercholesterolemia: III. The Approach to the Pathogenesis of Xanthomas, Arch. Dermat. & Syph. **15**:659-668 (June) 1927.

determination of the true nature of the tumor should depend on the type cell of the stroma. We agree that the type cell is the same in each instance and that the giant cells and foam cells are found in other lesions beside this one, but in each of our own cases one or the other was present and in most cases both were seen, so that we have come to the conclusion that they both are characteristic elements of this tumor and definitely belong there. In addition, we believe that if each tumor could be thoroughly sectioned and studied, all the previously noted characteristics would always be found.

Pigment: This appears as yellowish brown granules in sections stained by the hematoxylin and eosin method and imparts the berlin blue reaction with the iron stains. Bellamy,[21] Stewart and Flint,[36] Mason and Woolston,[49] Smith [131] and Janik,[50] besides others, agreed that this pigment is the result of the breaking up of the red corpuscles of extravasated blood in the tissues. According to Smith,[131] Mason and Woolston,[49] and Beekman,[8] this pigment produces the reddish brown color of the tumor. Miller,[46] quoted Wells as saying "that the brilliant orange-yellow color of the tumor is due to the presence of either carotin or xanthophyll pigments or both, which are normally present in the blood serum and are readily taken up and combined with cholesterol fatty acid esters, which are in themselves colorless."

The Type Cell: The type cell, or stroma cell, as has been mentioned, is morphologically similar to the endothelial cells, and in this conclusion many authors recently have concurred. We also believe that this is true. The fat content, although it may be a mixed type, spoken of by some as mixed steatosis, is in most cases, according to our belief and that of many others, made up chiefly of cholesterol or its esters and is in most instances intracellularly arranged.

Pathogenesis.—Each constituent of this tumor has been considered. What part does each play, and how does the tumor happen to develop? We do not agree with Geschickter and Copeland [132] and Wahlgren [69] in the conclusion that it develops and originates from the sesamoid bones. We found no histologic evidence for such an origin of any of the tumors in our series, and in going over the roentgenograms of the patients we were unable to find sesamoid bones at the site of the lesions except in a very few cases. The facts that a large number of these tumors arise on the extensor surfaces and other sites were sesamoid

131. Smith, D. T.: Method for Making a Differential Diagnosis Between Xanthomatous and Melanin Tumors from Frozen Sections, Based on a Study of One Hundred and Thirty Xanthomatous Tumors and Two Hundred Melanin Tumors, Arch. Surg. **8**:908-917 (May) 1924.

132. Geschickter, C. F., and Copeland, M. M.: Tumors of the Giant Cell Group: Pathologic Entity, Arch. Surg. **21**:145-156 (July) 1930. Footnote 55.

bones are conspicuous by their absence and that the tumors are all morphologically alike lead one to doubt the authenticity of this hypothesis.

We are convinced that the primary factor in production of this tumor is a preexisting alteration in the lipoid metabolism in which there is either a marked disturbance in the absolute values of the blood lipoids or, even more important, a disturbance in the ratios of the various constituents, chiefly that of cholesterol to cholesterol esters, and that the secondary factor is trauma or infection at the site of the lesion. Lubarsch [133] expressed the opinion that lymphatic stasis aids at this point in its production; this we are unable to support. We believe that at the time trauma or infection enters the picture minute hemorrhages occur within the tissue, lipoids and pigment are deposited by way of the circulation and a secondary response of the tissue occurs in which certain endothelium-like cells, foam cells, foreign body giant cells and adult connective tissue make their appearance. These changes develop slowly or rapidly, depending on the severity of the hemorrhage and the subsequent release of lipoids and pigment. As the process progresses, vascularity increases, more hemorrhages occur and the vicious cycle is established.

It has been shown that a severe injury will make one of these tumors grow rapidly, though it has been heretofore rather quiescent. This feature undoubtedly is due to an added large hemorrhage, as has been described. As this process is usually slow, a well defined capsule of connective tissue surrounds the mass, producing a more or less firm yellow to reddish brown tumor. In addition, we also are of the belief that in most instances this tissue response starts in the synovial lining of the tendon sheaths or in the synovial membranes of the joints. In some cases this feature is not recorded, either owing to an oversight on the part of the surgeon or because of failure to determine the site of the tumor accurately enough. In spite of this, we believe that in most cases, if a careful study and dissection are carried out, such a connection will be demonstrable.

Type of Lesion.—The question now arises, What is the true nature of this lesion? Is it a benign tumor, a malignant tumor or only an inflammatory tissue reaction to various irritants? What name should be given to it, and how should it be classified? We could name about thirty writers who believe it to be benign, but we shall refer the reader to the literature for this information. At any rate, most authors agree that it is always, under all circumstances, a benign growth. Harbitz [51] concluded that it is comparatively benign but should be classified probably as a sarcoma, whereas Hartman [81] expressed the opinion that

133. Cited by Weidman.[127]

there is always a potentiality of malignancy. Krogus [134] stated that xanthomatous lesions occurring on the fingers should be considered as benign, while those observed on the palm of the hand, foot or forearm sooner or later reveal a more malignant character. We agree that some of the tumors seen about the ankle are suspicious owing to their infiltrating nature, but in none of the cases were we ever able to find any signs of either local or general metastasis after a long period of observation, and as a result we have concluded that these lesions too are not potentially malignant.

Buxton,[42] Jebens,[62] Razemon and Bizard,[92] Spiess,[31] von Albertini,[135] Ragins,[10] Bellamy,[21] Stewart and Flint,[36] Görög,[59] Zumtobel,[70] Négrié and Canton,[89] Lecène and Moulonguet,[47] Pique, Brachetto-Brian and Fasciolo [72] and Heurtaux,[14] all believe that these growths are true tumors, Bonhomme,[18] Sonntag,[90] Kusnetzowsky,[114] Wegelin,[79] Foot,[136] Ewing,[112] Bloodgood,[24] Seyler [40] and Bussebaum [68] subscribed to the theory of the inflammatory (granulation tissue) nature of these lesions. Yamakawa and Kashiwabara [137] and Kurtz [54] concluded that they are inflammatory but that, in addition, there is a secondary disturbance of the lipoid metabolism. Wustmann [83] concluded that they are associated only with a cholesterol diathesis and are formed as a means of removing the excess of cholesterol from the blood. Montgomery [138] says that "they histologically represent fibrous stages of xanthoma with a foreign-body giant-cell reaction."

Sonntag's [90] argument for the inflammatory origin of this growth was that the stroma is typical granulation tissue, consisting of fibroblasts, lymphocytes, polymorphonuclear leukocytes, partly sclerotic scar tissue, blood pigment and crystals of cholesterol, surrounded by giant cells. In our group of tumors blood pigment, cholesterol crystals, foreign body giant cells and evidence of inflammation were observed.

While this tumor does not represent a simple inflammatory process, neither does it represent a true neoplasia comparable, for example, to

134. Krogius, A.: Xanthosarcomas in Tendon Sheaths, Finska läk.-sällsk. handl. **64**:102-121, 1922; abstracted, J. A. M. A. **79**:173 (July 8) 1922. Zur Kenntnis der s. g. Xanthosarcome der Sehnenscheiden, Acta chir. Scandinav. **55**:363-383. 1922-1923; Xanthosarcomas of Tendon Sheaths, abstracted, J. A. M. A. **80**:592 (Feb. 24) 1923. Footnote 39.

135. Cited by Kling and Sashin.[94]

136. Foot, N. C.: Report on a Case of Unusual Giant Cell Lymphogranuloma, Am. J. Clin. Path. **6**:278-285 (May) 1936.

137. Yamakawa, S., and Kashiwabara, M.: Lipoidemia and Xanthoma, Tohoku J. Exper. Med. **3**:317-332 (Dec.) 1922; abstracted, J. A. M. A. **80**:1495 (May 19) 1923.

138. Montgomery, H.: Xanthomatosis: A Systemic Disease, Proc. Staff Meet., Mayo Clin. **12**:641-644 (Oct. 13) 1937.

lipoma, myoma, carcinoma or sarcoma. Regardless of whether it is considered to be inflammatory or neoplastic or both, it is an undoubted entity which differs in its behavior from simple inflammation and from neoplasia and probably develops in the presence of a coexisting disturbed cholesterol metabolism and secondary trauma or infection. We are of the opinion that these tumors should be classified under the heading of the primary essential xanthomatoses and that they should be called xanthomas of the tendon sheaths and synovial membranes. Most writers believe that these tumors are benign; they fail to report any metastasis; we failed to find evidence of metastasis, and we therefore feel that the tumors should be called benign xanthomas of the tendon sheaths and synovial membranes. Finally, we agree with the classification presented by Thannhauser and Magendantz.[78]

Diagnosis.—Given a man or woman about 40 years of age with a firm, oval or round subcutaneous mass, about 2 to 3 by 2 cm. located on or associated with a tendon sheath, preferably the flexor, of the fingers, a mass that has been painlessly and slowly increasing in size; given, moreover, that the patient presents a history usually of previous trauma and that chemical study of his blood reveals an absolute increase in its lipoids or an alteration of the ratio of cholesterol to cholesterol esters and there is, in all likelihood, a xanthoma of the tendon sheath. If the lesion occurs in a joint—usually in the knee—the signs and symptoms are those of an internal derangement of that joint. There is usually a history of previous trauma. There may or may not be locking, depending on the type of tumor, that is, whether it is pedunculated or diffuse. The knee may be hot and painful or, in some instances, may cause little if any disturbance. The roentgenograms are usually normal. Aspiration of the joint reveals bloody fluid, but it must be remembered that bloody fluid may also be obtained from sarcoma of the synovial membrane, from the joint of a hemophiliac, from a joint involved by a hemangioma or from a joint in which there has been recent or old trauma. A determination of the bilirubin content of this fluid by the icterus index method with the patient's blood serum as a control is at times helpful.[139] In addition, if the cholesterol content of the aspirated fluid is high, this is positive evidence of the presence of a xanthoma (Kling and Sashin [94]).

Differential Diagnosis.—This tumor must be differentiated from chondroma, which is harder; lipoma, which is softer; carcinoma, which usually affects the skin; osteoma, which is harder and connected with the bone, and ganglion, which is usually on the extensor surface, near a joint and softer. Tumors of the muscle must be thought of, and

139. Kling, D. H.: Bilirubin in Effusions of the Joints: Method of Estimation and Significance, Arch. Surg. **20**:17-25 (Jan.) 1930.

tendovaginitis and tuberculous dactylitis are possibilities. If the lesion is in the joints, one must consider all those conditions producing an internal derangement of the joint, but here examination of the articular fluid is of great help. The final and true diagnosis, of course, must in most cases be based on biopsy and surgical removal.

Treatment.—Since these tumors have been definitely proved to be benign, without evidence of metastasis, conservative surgical treatment is the method of choice. Usually only local excision is necessary; if a recurrence takes place, as it does if the tumor has not been completely excised, a second excision should be performed, but never should a limb be sacrificed for what appears at first glance to be a sarcoma. The actual value of roentgen therapy in the treatment of these tumors is still questionable, and in most cases little, if any, response has been observed; however, this method will probably continue to be used as an adjunct to surgical removal and in the future may prove to be of benefit in those cases in which complete removal of the tumor is not possible. For the patient with high values for blood lipoid a diet low in cholesterol should be prescribed for three to four months. At the end of this period the blood chemistry should again be checked, the subsequent course being determined by these findings.

CONCLUSIONS

As a result of a study of the literature and of the records of 70 patients treated at the Mayo Clinic since 1919 we have been able to conclude that xanthoma of the tendon sheaths and synovial membranes is a benign lesion associated primarily with an alteration in the lipoid metabolism secondarily set off by trauma, infection, or both. It is classified under the general heading of the primary essential xanthomatoses.

REVIEW OF UROLOGIC SURGERY

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KIDNEY

Anomaly.—Weyrauch [1] stated that the anomalies of renal rotation, exclusive of ectopic and fusional deformities, may be divided into four main types: (1) ventral, or nonrotation (rarely excessive rotation), (2) ventromedial, or incomplete rotation, (3) lateral rotation (reverse or excessive rotation) and (4) dorsal (excessive or reverse) rotation.

The change in the position of the hilus renalis which takes place during early embryonic life results from a differential regional growth within the metanephros rather than from actual rotation of the entire organ. Hypotheses concerning the causation of anomalous rotation were advanced by Weyrauch, who emphasized such intrarenal forces as the organizing activity of the ureteral tree as opposed to any extrarenal mechanical influence. He discussed the clinical aspects of the condition and summarized 19 cases.

Bernhard-Kreis [2] reported a case of malformation in the urinary tract in which the patient, a girl 4 months old, died after four months

1. Weyrauch, H. M., Jr.: Anomalies of Renal Rotation, Surg., Gynec. & Obst. **69**:183-199 (Aug.) 1939.

2. Bernhard-Kreis, E.: Zur Kenntnis der angeborenen Fehlbildungen der ableitenden Harnwege, Schweiz. med. Wchnschr. **69**:221-223 (March 11) 1939.

of acute intestinal intoxication. Necropsy revealed bilateral duplication of the ureters. The two right ureters joined at the wall of the bladder. The right ureteral orifice into the bladder was so narrow that it was almost completely closed. One of the left ureteral orifices opened into a large ureterocele in such a way as to compress the other left ureter, which opened normally back of the ureterocele. Death was caused by infection of the urinary tract.

Torsion.—Weyrauch [3] stated that renal torsion constitutes an abnormal, acquired rotation of the kidney on its vertical, anteroposterior or horizontal axis and is classified as vertical, transverse or horizontal torsion, respectively. Combined torsion also is possible. Accurate clinical diagnosis of the type of torsion present may be reached by study of the pyelogram, supplemented by lateral views.

The factors which influence renal torsion are the length and the point of attachment of the vascular pedicle, the limitation of the mobility of the ureter in an upward direction, the firm, compact consistency of the kidney and the contour of the unyielding lumbar hollow.

Although it was found impossible to localize a mass to the peritoneum, retroperitoneum or kidney proper on the basis of the type of torsion produced, in general it may be said that a mass impinging upon the central portion of the kidney is more likely than not to produce vertical torsion, whereas one at either renal pole will cause the transverse or horizontal type.

Ventral displacement of the entire kidney or upper portion of the ureter is pathognomonic of a retroperitoneal tumor. Localized distortion of the renal pelvis other than mild compression is distinctive of an intrarenal mass. Enlargements of the liver and spleen may produce any type of renal torsion and result in a downward and medial displacement of the kidney.

Surgical Technic.—Chauvin and Zananiri [4] discussed the value of heminephrectomy in cases of supernumerary ureter in which abnormal outlets result in incontinence. Only 40 such cases in which heminephrectomy has been done have been published; these include 14 collected by Dossot (1926) and by Dewailly (1935), who added no new ones, and 25 collected by Eisendrath (1938), in which the operation was bilateral in 2 and was done for vaginal ectopy in 10 and for vulvar ectopy in 13. The single case of Pick and Hendrick brings the total to 40. In all these cases heminephrectomy was satisfactorily accomplished.

3. Weyrauch, H. M., Jr.: The Significance of Renal Torsion in the Diagnosis of Retroperitoneal Tumors: Use of the Lateral Pyelogram, J. Urol. **41**:877-892 (June) 1939.

4. Chauvin and Zananiri: Héminéphrectomie pour abouchement vulvaire d'un urétère surnuméraire, J. d'urol. **48**:139-143 (Aug.) 1939.

It is surprising, however, to note the number of complete nephrectomies that are still done for this type of malformation.

Only two contraindications exist for heminephrectomy in such cases: One is the uselessness of conserving the normal kidney because it is too small; the other is the existence of a single pedicle opening into the kidney that is to be removed. Both are exceptional, and the second is not an absolute contraindication, since one pole in a solitary kidney may be safely resected.

Since kidneys of this type are always infected, vaccination of the patient before operation with a vaccine prepared from his septic urine is desirable. In the case reported, there had been constant incontinence from birth in a girl 18 years old in whom the power of voluntary micturition was nevertheless present, with normal functioning from four to six times a day. Cystoscopy on the right side revealed two orifices, of which one was blind 3 cm. from the outlet and the other was normal. Urography demonstrated one normal pelvis on each side, thus suggesting probable bilateral double kidney, with the supernumerary half kidney on each side functioning too weakly to give an image. Only by meticulous examination of the vulva was there discovered, on the left side, behind the normal urinary meatus and about 1 cm. distant from it, at the edge of the vaginal orifice, a minute ectopic ureteral meatus, which would permit the entrance of only a fine ureteral sound. The urine from this meatus contained pus and many colon bacilli. Retrograde urography, accomplished with difficulty through this minute meatus, disclosed megaloureter, with an enormous tube having a kink at its pelvic end. Its diameter was 4.5 cm. in places, and it contained a few minute calices at its upper end. Roentgen examination of the lower part of the pelvis of the kidney on the same side showed that the ectopic ureter crossed the normal one several times, describing many sinuosities. This anomalous kidney, or half kidney, was situated above the sound kidney and about 2 cm. away from it. After its removal, recovery of the patient was uneventful for twenty-five days, at the end of which a fistula opened at the level of the incision, from which urine poured in abundance. The authors did not accept the explanation usually given in such cases, that a small amount of the pelvic wall had been left behind inadvertently, for they knew that this was not the case. They thought, rather, that the fistula was caused by secondary necrosis, the site of which could not be determined. After three weeks the fistula closed, and the patient experienced no further trouble.

Stone.—Granoff [5] presented a case in which a perinephric abscess on the left was accompanied by or was secondary to pyonephrosis with

5. Granoff, M. A.: Migration of Renal Stones Associated with Pyonephrosis and Perinephric Abscess into Lung, J. Urol. **42**:302-310 (Sept.) 1939.

nephrolithiasis on the same side and in which the treatment had been surgical drainage twelve years prior to the death of the patient, followed by an intermittent discharge of pus and stones through the surgical incision for many years. Necropsy, following the death of the patient from cardiac failure, revealed an old, fibrous, contracted pyonephrotic left kidney, enclosing renal stones, and a sinal tract leading from the pelvis of this kidney to a cavity in the lower lobe of the left lung, which also contained renal stones physically and chemically identical with those found in the kidney. The stones had migrated from the kidney into the lung.

Although the thoracic complications of perinephric abscess and pyonephrosis are not common and occur principally in cases of long duration, their incidence is about as great as that of abdominal complications.

Invasion of the lung by a suppurative process requires preceding localized adhesive pleuritis; otherwise, empyema results.

Higgins[6] says that prior to 1933 the incidence of postoperative recurrence of renal calculi at the Cleveland Clinic was 16.4 per cent. Since that year it has been reduced to 4.9 per cent by adding the high vitamin A, acid ash or alkaline ash diet to other postoperative measures, thereby controlling the *p*H of the urine.

The relation between infection and the formation of primary or recurrent calculi has been stressed for a long time. In Higgins' series of 200 cases of recurrent renal calculi, there was a coexisting renal infection in 81.5 per cent, whereas the urine was sterile in 18.5 per cent. Recurrent stones associated with infection were usually large and were composed of phosphates, carbonates or mixtures of these salts. Stones recurring in sterile urine usually were small and were composed of uric acid, cystine or oxalates.

Recurrence of calculi is more likely when an infection is present that is caused by organisms which possess the property of splitting urea, thus producing persistently alkaline urine and precipitating the alkaline salts, that is, phosphates and carbonates. In Higgins' series 9 per cent of the bacilli and 18 per cent of the staphylococci were of the urea-splitting type.

Focal infections were common, but there was no apparent relation between the organisms obtained by culture from these sites and those isolated from the urine.

Urograms taken intravenously showed evidence of urinary stasis in 72 per cent of the cases, although it was difficult to form an opinion as to whether stasis preceded or was subsequent to the formation of calculi.

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6. Higgins, C. C.: Factors in Recurrence of Renal Calculi, J. A. M. A. **113:** 1460-1465 (Oct. 14) 1939.

Experimental and clinical observations have demonstrated the existence of a relation between deficiency of vitamin A in the diet and formation of renal calculi. The history alone does not provide sufficient evidence to enable one to state whether a patient is receiving or utilizing adequate amounts of vitamin A, and a biophotometric test should be a part of the examination of every patient who has calculous disease. Higgins and his associates prescribe vitamin A as a routine postoperative measure.

Hyperparathyroidism has been assigned an important role in renal lithiasis by various authors. However, in Higgins' series it was present in only about 0.1 per cent of the cases.

Metabolic factors may play an important part in the recurrence of stone. Cystinuria frequently is associated with calculi. Increasing the solubility of the cystine in the urine by the administration of alkalis diminishes the possibility of the formation or recurrence of stone. Likewise, attention to diet, metabolic factors and the maintenance of a *p*H of the urine unfavorable for the deposition of crystals are important in preventing the formation of stone and the recurrence of the other types of excretory calculosis such as oxaluria, phosphaturia, xanthinuria and uraturia.

Surgical precautions for the reduction of recurrences consist of minimization of trauma in handling the kidney, performance of pelviolithotomy instead of nephrolithotomy whenever possible, thorough lavage of the pelvis and calices, followed by use of a suction tube to remove clots, debris, fragments of stones or minute stones and sand, and adequate drainage of the kidney whenever nephrotomy is necessary or when a high degree of infection is present.

Tuberculosis.—Herbst [7] stated that the factors involved in the mortality and morbidity of renal tuberculosis are the recognition of Mycobacterium tuberculosis in the urine, the general resistance of the individual, the procedures instituted in treatment and the provision of adequate facilities and detailed direction of every individual affected.

The indications for search are: (1) unilateral renal infection, (2) hematuria with no obvious explanation, (3) pyuria with no organisms demonstrable by ordinary staining methods, (4) persistent pyuria of any kind, (5) cystitis which does not respond to treatment after a reasonable period, (6) pyuria or dysuria in persons who have a history of tuberculosis or active extraurinary tuberculous lesions, with nodular lesions in the seminal tract, and (7) urographic evidence of the destruction of renal tissue.

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7. Herbst, W. P.: Renal Tuberculosis as a Community Problem, J. A. M. A. **113**:371-373 (July 29) 1939.

The general resistance of the patient was cited as the most important single factor involved in the problem. Herbst pointed out that renal tuberculosis was found clinically by Thomas in approximately 4 per cent of the patients in Glen Lake Sanitarium. The economic status of a community influences the incidence. Climatic influences are vital. In certain climates there is practically no urinary tuberculosis, even though pulmonary tuberculosis occurs. Food and vitamins are important in the general factor of resistance.

All things being equal, the sooner an advancing destructive lesion is recognized and removed the higher will be the percentage of cures and the lower will be the percentage of mortality and morbidity.

Medical societies should survey the situation and lead in accomplishing the following: standardization and provision of facilities for recognizing Myco. tuberculosis in the urine, enlistment of the cooperation of civic agencies, lay organizations and local health departments in seeing that there are adequate facilities for hospitalizing and caring for patients and improvements in living conditions in general and standardization of laboratory methods and facilities for the identification of bacilli.

Community action on the part of any medical society in such endeavors as those mentioned previously would result in some degree in dispelling the prevailing public opinion that physicians are obstructive to the acquisition of cheap or free medical service and, what is more important, would stamp physicians as authoritative, dynamic and sympathetic leaders in solving community health problems.

Keyes [8] again advised closure of an incision in the loin without drainage after nephrectomy for tuberculosis.

He recited in brief the history of lumbar closure after nephrectomy for tuberculosis. In 1912, W. J. Mayo advised surgeons to close the wound in the loin after filling it with salt solution to displace the air, without drainage, unless the wound is soiled by rupture of the kidney or of its pelvis or unless a perinephritic abscess is present. He repeated this injunction in 1915, and Verne Hunt, in 1923, wrote as follows:

> A sinus persisting after nephrectomy (for tuberculosis) is due to incomplete removal of the diseased tissue, persisting infection in the ureter, and the institution of drainage. The insertion of drainage tubes after nephrectomy for kidney tuberculosis is as inadvisable as for tuberculosis elsewhere.

A rigorous technic must be adhered to. Mayo's precaution of filling the wound with sterile solution to replace air and prevent scrotal emphysema, such as has been reported by both Aschner and Keyes, must be observed. It has been Keyes' custom to fill the loin with a 1:10,000 solution of acriflavine.

8. Keyes, E. L.: Closure of Loin Wound Without Drainage After Nephrectomy for Tuberculosis, J. Urol. **42**:496-499 (Oct.) 1939.

Keyes' first nephrectomy for tuberculosis was done in 1906. The patient had perineal and perinephric abscesses. A clamp was left on the pedicle. He died fourteen years later of tuberculosis. Clamps were left on the pedicles of the first 5 tuberculous kidneys which Keyes removed and on many others thereafter. He had no trouble after he learned that the clamp must not be unlocked before the fourth day or removed before the fifth. The loins in which clamps had been left healed badly. Seven sinuses lasted until the death of the patient, or at least two years, whereas only 1 healed in a month, 3 healed in six months and 5 healed in from seven to nine months.

Drained wounds gave better results. Four healed in a month, 1 in three months, 1 in six months, 1 in a year and 1 in thirty months, and 1 persisted until the death of the patient.

Keyes found that in his operations performed since 1912 by the Mayo technic, 29 wounds had primary union, and 20 were known to have reopened.

Forty-one of 49 sutured wounds healed in three months. Only 66 per cent of drained wounds healed as quickly as the sutured wounds.

Of the patients who survived the removal of tuberculous kidneys and were followed more than a year after operation, clamps had been left on the pedicle in 13. Four of these patients died of tuberculosis or of renal insufficiency. Of the 23 patients whose wounds were sutured without drainage and who were followed, 10 died of tuberculosis and 13 (more than half) remained alive and well.

After his experience, Keyes was profoundly impressed with the conclusion that in cases of renal tuberculosis the drain which is placed in the loin is responsible for mixed infection and for the sinus in the loin. If the sinus opens after complete closure, the opening need not imply a tempestuous or a prolonged convalescence. Today, drained operative wounds resulting from nephrectomy for renal tuberculosis heal well; undrained wounds heal better. Keyes stated the belief that the results of modern atraumatic surgical technic will be better than those he has obtained since the war, that is, closure of 21 of 23 incisions in the loin without any drain whatever and also of 2 sinuses, only 1 of which was a grave one. Surgeons are no longer timid about tying the renal artery; they should not be timid about closing the incision in the loin occasioned by nephrectomy for tuberculosis.

And by "complete closure" is meant no drain whatever.

Hydronephrosis.—Priestley [9] stated that many advances have been made during the past twenty years in the conservative surgical treatment of hydronephrosis, so that now many kidneys can be preserved which

9. Priestley, J. T.: The Conservative Surgical Treatment of Non-Calculous Hydronephrosis, Surg., Gynec. & Obst. 68:832-841 (April) 1939.

previously would have been considered irreparably damaged and would therefore have been removed. The exact type of operation indicated depends on the significant observations in each case.

If anomalous vessels are present and it is demonstrated that they are of importance in the production of hydronephrosis, one of several surgical procedures may be employed. The vessels may first be temporarily occluded to determine their importance in the blood supply of the lower pole of the kidney. If no undue change in color takes place during compression for several minutes, the vessels may be severed. Should the lower pole become very dark and a sharp line of demarcation appear between it and the main portion of the kidney, the vessels cannot be divided without producing an infarct in it. Under these circumstances, if the vessels are definitely obstructing the ureter, the ureteropelvic juncture may be severed and the ureter reimplanted into the pelvis on the opposite side of the vessels. If pyelectasis associated with anomalous vessels is extensive and the pelvic wall is thin and flabby, resection of the renal pelvis also may be performed.

High insertion of the ureter into the pelvis also may be a factor in the production and maintenance of hydronephrosis. This abnormality may be corrected by any of a variety of surgical procedures. In general, an operation which does not entirely sever the ureter from the pelvis is to be preferred, when feasible, because the blood and nerve supply to the upper portion of the ureter is not disturbed by it. One of the simplest and most satisfactory procedures consists of simple anastomosis between the ureter and pelvis, so-called ureteropyeloneostomy. In this operation a new opening is made between the most dependent portion of the pelvis and the ureter at the corresponding level. A second procedure, similar in principle to the Finney pyloroplasty, may be employed. The adjacent portions of the ureter and pelvis are incised in a straight line, and the cut edges are then united, the posterior edge of the pelvis to the posterior edge of the ureter and the anterior edge to the anterior edge. Another operation which Priestley has not seen described in the literature but which he has employed with satisfactory results is performed as follows: A longitudinal incision is made in the upper portion of the ureter which lies adjacent to the pelvis. This incision is carried down to a level which corresponds with the most dependent portion of the pelvis near (approximately 1 cm. from) the renal parenchyma of the lower pole. The dependent portion of the pelvis which lies between the lower pole of the kidney and the ureter is then resected, a wedge-shaped section being removed, with the base of the wedge directed downward and the apex reaching upward to the level of, or a little above, the ureteropelvic juncture. The anastomosis between the remaining portion of the pelvis and the longitudinal incision in the ureter is then completed in the

usual manner. The Y type of operation described by Foley also may be used in this type of case, although it was described by the author for the treatment of stricture of the ureteropelvic juncture.

Somewhat less conservative operations may at times appear advisable. Occasionally, it may seem necessary to sever the ureteropelvic juncture completely, to resect the upper portion of the ureter which lies adjacent to the pelvis and to reimplant the upper end of the ureter in the lowest portion of the pelvis. This procedure may or may not be combined with resection of the pelvis. If the pelvis is resected, the line of incision may be carried to within 1 cm. of the renal parenchyma, both on the anterior and on the posterior wall. The ureter is then inserted at the lower angle of the pelvis. This type of operation is best reserved for large hydronephroses in which the pelvis is thin and markedly dilated and has flattened and narrowed the upper portion of the ureter.

Many types of surgical procedure have been employed for the correction of hydronephrosis caused by narrowing of the lumen of the ureteropelvic juncture, with variable results. One of the simplest procedures technically employs the principle of the Heineke-Mikulicz pyloroplasty and is known as the "Fenger operation"; however, ultimate results following this type of procedure have not been satisfactory. Schwyzer modified Fenger's operation by using a Y-shaped incision of which the diverging limbs are placed on the pelvis and the descending limb continues down the ureter. This incision is closed so that the dependent point of the triangular flap created on the pelvis is approximated to the lower end of the incision in the ureter. Foley modified this operation by placing the diverging limbs of the Y incision downward on the lower portion of the pelvis directly opposite the upper end of the ureter.

Occasionally, cases of abnormal renal ptosis associated with some degree of hydronephrosis and with pain, which appears to be of renal origin, are encountered. If the clinical diagnosis has been established and if definite stasis has been actually demonstrated, a pleasing result may follow immobilization of the kidney in such a position that undue angulation or kinking of the ureter or ureteropelvic juncture does not occur. Elaborate methods of fixation are unnecessary.

Hydronephrosis which results from various abnormalities in the lower portion of the urinary tract and from pathologic conditions entirely extrinsic to the urinary tract is not at all uncommon. In cases of this type, however, a local conservative operation on the kidney is seldom indicated. Occasionally, the surgeon encounters definite hydronephrosis without adequate anatomic explanation for its development.

At times, hydronephrosis may develop, usually in one segment of a duplicated kidney but occasionally in both. When hydronephrosis develops in one segment only and the other half of the kidney is functioning normally, a conservative operation rather than nephrectomy is desirable. In Priestley's experience, heminephrectomy is the operation which has given the most uniformly satisfactory results. The line of resection should be placed so that neither a calix nor a pelvis is opened. If the involved segment is excised as a wedge-shaped section, the edges of the defect in the remaining portion of the kidney can be approximated. Occasionally, a unilateral fused kidney presents a definite hydronephrosis in one segment, with resultant symptoms. Generally, this may be treated in the same manner as hydronephrosis in one segment of a duplicated kidney. Hydronephrosis sometimes develops in an ectopic kidney. Nephrectomy gives the most uniformly satisfactory results in the treatment of kidneys of this type, provided that the other kidney is in good condition. Because of the abnormal position of the kidney and its unusual blood supply, conservative plastic operations are less often successful than in cases in which the kidney is normally placed. A horseshoe kidney which shows evidence of hydronephrosis usually presents a clearcut problem at the time it is exposed surgically. According to the causes of hydronephrosis, the surgical indications will vary. Ordinarily, plastic operations on the ureter and pelvis can be performed as easily on a horseshoe kidney as on a single kidney.

There are certain general surgical considerations that seem important in obtaining satisfactory results after plastic operations on the kidney. Absorbable suture material is universally employed. A single row of sutures is adequate. Drainage established by nephrostomy is widely recognized as a valuable adjunct to practically every plastic operation performed on the ureteropelvic juncture. With such provision for immediate drainage during the early postoperative period, the incidence of secondary nephrectomy and functional failure of operation is definitely reduced. The use of an indwelling catheter which traverses the lower part of the pole of the kidney, the lower calix, the pelvis, the ureteropelvic juncture and the ureter in order, so-called ureteronephrostomy, when any plastic procedure has been carried out at the ureteropelvic juncture, is of definite value. This catheter should remain in place for some time. Fixation of the kidney in a position which is most favorable to good drainage at the conclusion of a plastic operation is generally advisable. The wound always should be drained.

Stirling [10] presented 3 cases of advanced pyelectasis; the first is of interest because of the size of the tumor, which contained more than

10. Stirling, W. C.: Massive Hydronephrosis Complicated by Hydro-Ureter: Report of Three Cases, J. Urol. **42**: 520-533 (Oct.) 1939.

2,000 cc. of fluid, and the question of diagnosis; the second was a rare case of subcapsular pseudohydronephrosis, and the third was one of advanced hydronephrosis and hydroureter resulting from carcinomatous infiltration of both ureteral walls.

Marion [11] expressed the view that the urologist's attitude toward large hydronephroses, which in the past have been removed without discussion or scruple, should be more and more one of conservation. When a hydronephrosis of great size is met, it is absolutely necessary to explore the opposite kidney, which is often equally dilated, and to learn its condition. Such a hydronephrosis is to be treated (1) by suppression of the obstacle that caused it, which may be a polar vessel, a kink or a ureteral or pelvic stone, (2) by elevating the kidney as high as possible and (3) by prolonged drainage of the kidney, until the pelvis has returned to approximately its normal size or until it tends to no further diminution of size. Capitonnage of the renal pelvis and the placing of an indwelling ureteral catheter may be useful aids to reposition of the kidneys and to nephrostomy.

Nephrectomy is permissible only when the hydronephrosis is such as to make it impossible to bring the pyeloureteral region to view and to remove whatever is serving as an obstacle. Even then it should be resorted to only if the other kidney is sufficient in function. If this is not the case, such enormous hydronephroses should be treated by nephrostomy.

Sometimes a great hydronephrotic sac forms quietly and without painful symptoms of any kind. When attention is finally drawn to it, pyelographic examination is the means by which both the fact and the degree of dilatation can be determined; the pyelograms always should be bilateral, for in more than two thirds of cases the condition exists on both sides.

The rule is to conserve the kidney as long as the function of the parenchyma can still be assured; while this lasts, nephrectomy is not the treatment of choice. Marion has often saved hydronephrotic kidneys which, because of their dilatation, seemed valueless. It is evident that under these conditions the renal pelvis and calices do not resume their normal appearance, but the renal parenchyma takes on a much better function than was present when there was retention, and there is no longer aggravation of the lesion after the obstacle has been removed.

Conservation of such kidneys will be brought about by overcoming of the obstacle, high fixation of the kidney and drainage established by nephrostomy. Pyelographic examination will show how long this drain-

11. Marion, G.: Traitement conservateur des grandes hydronéphroses, J. d'urol. 48:5-19 (July) 1939.

age should continue; usually the period will be three weeks to one month. A second pyelogram should then be made for comparison and a third a few weeks later. If the kidney is still diminishing, drainage may be continued longer yet. Again, injection of opaque fluid by the drainage catheter will show whether the fluid passes easily into the ureter and also will provide an idea of the time when the drain may be removed. After its removal, closure of the fistula is usually rapid if permeability of the ureter at its pelvic end is completely reestablished.

Results are to be regarded from two points of view, anatomic and functional. From the anatomic standpoint, it is certain that the normal size and relations never will be regained after large hydronephroses. But functionally the results of conservative treatment are almost always excellent; patients are relieved of their former suffering, and renal function, if it is not wholly normal, is at any rate notably improved. If results are not in the end all that has been hoped for, it is still possible to do nephrostomy or nephrectomy, according to conditions.

Tumor.—Barney and Churchill [12] reported a case of adenocarcinoma of the kidney (hypernephroma). The patient was a woman of 52 in whom roentgenologic evidence of a metastatic nodule in the lung was the first sign of disease. Nephrectomy was performed five months later, and fifteen months after nephrectomy the metastatic growth in the lung was excised by subtotal lobectomy. The patient was alive five years later, in good health and without evidence of disease.

Barney and Churchill emphasized two points in their case. The metastatic tumor in the lung from the adenocarcinoma of the kidney was not radiosensitive. If a metastatic growth apparently is solitary and accessible to surgical removal, it is definitely worth while to undertake its removal as well as that of the primary growth.

Perinephritic Abscess.—Foulds [13] reviewed the records of 49 patients suffering from perinephric abscess. The group consisted of 27 cases of so-called primary metastatic abscess, of which the abscess was secondary to preexisting renal disease in 16 and related to disease in adjoining organs in 6.

Foulds pointed out that in many cases the diagnosis was made late. Various aids to diagnosis were used. The shadow of the psoas muscles on the affected side was obliterated in approximately 70 per cent of the patients, and in many of the remainder it was blurred or indistinct. Roentgen evidence of scoliosis with the concavity toward the side on which the abscess was situated was noted in slightly less than half of

12. Barney, J. D., and Churchill, E. J.: Adenocarcinoma of the Kidney with Metastasis to the Lung, J. Urol. **42**:269-276 (Sept.) 1939.

13. Foulds, G. S.: Diagnosis of Perinephric Abscess, J. Urol. **42**:1-4 (July) 1939.

the cases. Scoliosis is produced by spasm of the lumbar muscles, caused by the abscess. Foulds pointed out that physical examination will reveal this spasm before it can be shown to exist by radiologic procedures and described a new sign in the diagnosis of perinephric abscess. He instructed the patient to stand erect and then to bend over, first to the suspected side and then to the contralateral side. The spasm of the lumbar muscles on the side of the abscess could be abundantly demonstrated by the ease with which the patient bent to this side and his inability to bend to the opposite side. Bending toward the side in which the abscess is situated caused little or no pain, but any attempt to bend to the contralateral side caused severe pain. This sign was noted in 10 successive patients, and for 3 of these 10 it enabled the author to make distinctly earlier diagnoses than would have been possible by other means. The average duration of symptoms prior to the patient's entering the hospital in this series was three and four-tenths weeks. Another nine days elapsed between admission of the patient to the hospital and operation. Any procedure which will shorten this period should prove to be useful.

Ptosis.—Squillario [14] recognized three types of nephroptosis: (1) a movable kidney that is entirely silent, with neither subjective nor objective symptoms, (2) a movable kidney with more or less severe subjective symptoms but little disturbance of function or with slight pathologic aspects and (3) a movable kidney with both subjective symptoms and objective anatomic changes, which may be grave.

The treatment of the first group is medical, consisting in the use of a belt and the administration of urinary antiseptics. For the second group, nephropexy is indicated to relieve pain, digestive disturbances and eventual nervous symptoms. For the third group, with which the most common complications are hydronephrosis, pyonephrosis with attacks of renal strangulation and sometimes grave hematuria, caused by venous stasis, treatment must be first addressed to the complication and then completed by nephropexy. The conditions may call for resection of an overdilated renal pelvis, freeing of intestinal adhesions, fixation of a ptosed colon or removal of an appendix.

General points to be observed when nephropexy is to be done are (1) freeing the kidney, (2) placing it in its new site and fixing it, (3) inspecting the renal pelvis and ureter, (4) liberating the ureter and placing it in a new direction, (5) making as little change as possible in the renal pelvis and (6) varying the technic according to the complications that may be present. In many cases, perinephritis and pericolitis

14. Squillario, G.: Sulle ptosi renali. Terapia chirurgica della ptosi renali, Arch. ital. di urol. **16**:127-151 (March-April) 1939.

which have been caused by inflammation of the kidney and the colon may be the cause of the patient's pain. Kinks and compressions may be found, or the surgeon may come on abnormal veins.

In the presence of a movable kidney, the typical lumbar incision is made below the twelfth rib, with a view not only to facilitating the freeing of the kidney and permitting fixation, but also to creating a more ample bed for the kidney, in which it will not be compressed.

Nephropexy may be done by fixation, which may be accomplished by transfixing of the renal parenchyma or partial or total decortication of the kidney, or by construction of perirenal "hammocks," which support the organ and allow the adhesions to form.

Caporale in 1934 made experiments in fixing the kidney by the perirenal subcapsular placement of a catgut ribbon, passing loops of the ribbon through the incisions, both longitudinally and transversely, to rope the kidney up. Because, however, it was difficult to obtain the material of this catgut ribbon, he substituted the perirenal subcapsular placement of catgut threads, running a series of four threads vertically and four transversely through the substance of the capsule, until these completely surrounded and supported it, like a hammock. After tying, the two upper ends were fixed in the tenth intercostal space, and the transverse threads were attached in the lumbar space. The technic is improved by exerting different traction on the various threads, so as to place the kidney in the best possible position, as near as possible to the normal.

In experiments on dogs, Caporale found that after seventy days no signs of the sutures could be found on the capsule. After fifty days solid adhesions had formed between the kidney and the posterior wall, consisting of fibrous bundles lying transversely to the direction of the capsule. A lesion of the parenchyma was not found in any dog.

This method is now regularly used in the clinic of the University of Turin, with excellent operative results. Provided the diagnosis is accurate, the proper indications present, the technic correct and the postoperative care suitably carried out, nephropexy by Caporale's method justifies all the hopes that have been pinned to it.

Cyst.—Thevenard [15] drew attention to a case in which he made the clinical and histologic diagnosis of pseudocancerous cyst of the kidney. In a man 66 years of age, the first indication of the presence of such a cyst was an extensive, sudden, spontaneous hemorrhage from the urinary tract, unaccompanied by pain. Three weeks later, hematuria of the same character again occurred, lasting thirty-six hours. An enormous mass was palpated on the left side, with smooth, regular outline, having all the characteristics of a renal tumor.

15. Thevenard, P.: Kyste solitaire du rein à forme pseudo-concéreuse, J. d'urol. **47**:478-482 (June) 1939.

At operation a polar vessel was found and ligated; a large, two-lobed cyst occupied the hilum, with two veins passing in front of it and the other elements of the pedicle behind. Section of these two veins made it possible to draw the kidney forward and give access to the principal pedicle, thus accomplishing nephrectomy without other difficulty. The cyst occupied the entire kidney, leaving only a thin layer of parenchyma, with a few cystic nodules on the surface of the organ. It was multilocular, with two principal cavities, and its content was serous. At the upper pole could be seen the source of the hemorrhages, a dark spot, intensely congested, in one of the pyramids.

The pyelographic image taken in vivo was perfectly superimposable on that of the operative specimen, but the former was more instructive, the lower calix of the cyst appearing as if stretched between two fixed points, one renal and the other ureteral; freeing of adhesions at operation caused the specimen thereafter to present only the appearance of common hydronephrosis.

Although resection is evidently the ideal treatment for such a cyst, the intrahilar position made this type of operation rather complicated for the elderly patient concerned, and nephrectomy seemed safer than heminephrectomy, especially since there was basis for fear that malignant degeneration might have already begun, in view of the evident long duration of the cyst. The fact of the occurrence of two profuse hemorrhages served to strengthen this view. Although histologic examination showed this cyst to be benign, some other similar instances of the condition have been malignant, and it seemed unwise to risk the development of carcinoma a few months later in the kidney that served as its host. In such cases it would appear that performance of nephrectomy is preferable, but lack of statistics on the subject makes a definite judgment impossible at the present time.

Carbuncle.—Ingrish [16] reported 11 cases of metastatic staphylococcic infection of the kidney, proved by operation.

The primary focus in each of the 11 cases was a cutaneous suppurative lesion of no certain situation. The organism isolated from the involved kidney was Staphylococcus aureus.

A rather frequent diagnostic physical sign is a stony-hard costovertebral rigidity on the affected side. This is caused by a tremendous perinephric reaction and marked thickening of the fatty capsule, which becomes leathery. Fulness over the renal angle is characteristically absent except in cases in which an associated perinephric abscess is present.

16. Ingrish, G. A.: Carbuncle of the Kidney: Report of Ten Cases, J. Urol. **42**:326-340 (Sept.) 1939.

The urine in the majority of cases was characteristically normal except for a slight trace of albumin, which undoubtedly was the result of toxic nephritis.

Intravenous urography in conjunction with the careful interpretation of a flat roentgenogram, when localizing symptoms are present and a history of a recent cutaneous lesion has been evinced, usually will suffice to make a diagnosis. Cystoscopic examination is seldom indicated.

Lesions on the anterior surface of the kidney are associated with abdominal symptoms which at times lead to an erroneous diagnosis of intra-abdominal disease.

Ingrish stated that considerable confusion and differences of opinion exist in the literature as to treatment. As conservative treatment with incision and drainage failed to effect a cure in 2 of the 11 cases, it is felt that the toxic patient, especially if more than one lesion on the kidney is present, should be subjected to nephrectomy rather than to some form of conservative surgical intervention.

The postoperative management of the patients is important, as they show evidence of myocardial damage caused by prolonged and severe sepsis and for that reason they should be kept at rest in bed until the pulse approaches normal.

Renocolic Fistula.—Ratliff and Barnes [17] reported 2 cases of renocolic fistula between the left kidney and the descending portion of the colon. In 1 the condition was long standing and was tuberculous. The patient withstood nephrectomy but died after subsequent surgical intervention for closure of a fecal fistula. The other patient was acutely ill. The fistula was demonstrable by both pyelography and retrograde ureteral injection of methylthionine chloride (methylene blue). Recovery with closure of the fistula followed prolonged conservative treatment with ureteral drainage and pelvic lavage.

These cases emphasize the value of conservative treatment. It is apparent that in the first case, in which sinuses were present, drainage by catheter probably would have been of no avail, particularly in view of the tuberculous background. Nephrectomy was conservative treatment in this case. In the second case drainage by catheter was conservative therapy. In the presence of minimal nontuberculous infection without the complications of sinuses or ureteral obstruction, conservative treatment is justified.

Hydrocele.—Woodruff and Rupert [18] reported a case of hydrocele of the kidney. The patient was a boy 7 years of age who had multiple contusions and abrasions on the left side of his body following an auto-

17. Ratliff, R. K., and Barnes, A. C.: Acquired Renocolic Fistula: Report of Two Cases, J. Urol. **42**:311-316 (Sept.) 1939.

18. Woodruff, S. R., and Rupert, H. S.: Hydrocele Renis, J. Urol. **41**:919-927 (June) 1939.

mobile accident. He had severe abdominal pain in the upper left quadrant. A diagnosis of hydronephrosis was made, and an operation was performed the following day. A large accumulation of fluid was found in a well developed sac adherent to the surrounding tissues, which entirely surrounded the kidney. The first procedure was merely to drain the sac, and at a later operation the kidney was removed.

Woodruff and Rupert stated that the treatment for this condition—hydrocele renis—is surgical. They stated the belief that in instances in which there is a massive collection of fluid a two stage operation is safer than other measures and should be employed.

Lipomatosis.—Cella [19] collected 70 cases of lipomatosis of the kidney from the literature, to which he added 3 of his own. Gathering all into the form of a table, he showed that in every case the kidney had been altered by toxinfectious or calculous processes or had undergone sclerosis, prior to the infiltration of fatty deposits, which gradually replaced the parenchyma and led to complete destruction of the organ. Such changes always precede the infiltration or replacement by adipose tissue.

Renal lipomatosis is a rare disease, found especially between the fiftieth and sixtieth years of age, more frequently on the left side, exceptionally on both and slightly more frequently among females than among males. The fat is an extrarenal tissue, derived from hypertrophy of the pelvis, which, following the elements of the renal pedicle, in general the vessels, infiltrates the parenchyma of the kidney. It can be readily differentiated from perirenal lipomatosis and from lipoma of the fatty capsule or of the renal parenchyma.

There are no pathognomonic symptoms, and, accordingly, the diagnosis of renal lipomatosis is clinically only presumptive. In fact, every case on record constituted a surgical or an anatomic observation. Since patients having the condition do not have a diagnosis preoperatively, treatment naturally is directed toward combating the diseases which are its forerunners, such as infection, calculosis and other pathologic processes. But when, during the course of operation on the kidney, the renal parenchyma is found to be the seat of lipomatosis, nephrectomy or, better, removal of the entire fibrolipomatous mass is the treatment of choice. The surgeon should bear in mind, however, that because of the development of perirenal fat, which sometimes encircles the lipomatous kidney, the topography of the tissues surrounding the kidney is modified, and he must be on guard against causing the complications and accidents (hemorrhages or rupture of sacs with purulent content) which may arise when a kidney in this condition is operated on.

19. Cella, C.: Sulla lipomatosi renale, Arch. ital. di urol. **16**:87-126 (Jan.-Feb.) 1939.

The prognosis depends on the causative background of the condition, and since the infectious and calculous conditions persist, the course is generally slow and progressive. In advanced stages of the disease all function of the kidney is lost. If it is not removed, it will deliquesce and fill the entire cavity with purulent fluid and with calculi, representing remnants of the calices and the pelvis. Finally the infection extends to the bladder and thence to the other kidney, and the patient will die, as occurred in 1 of Cella's cases. Usually, however, the mass can be discovered and removed before such an extreme condition arises.

The condition sine qua non for fatty infiltration of the kidney is primary atrophy of the renal parenchyma, which often occurs with chronic suppurative processes associated with calculous or inflammatory processes. Rickards regarded this infiltration as physiologic compensation, always secondary to degeneration of the parenchyma. The infiltration may be limited to small zones of medullary substance, in early stages, or may involve the entire organ, in more advanced ones.

Fatty replacement of the kidney is in the opinion of Hamm and de Veer [20] a frequent accompaniment of a variety of lesions leading to atrophy or destruction of renal tissue. They selected 6 cases to illustrate mild, moderate and advanced grades of this condition. In 5 cases stones and infection were present. According to their observations, extensive fatty replacement of the kidney is encountered only among obese patients. The process is one of hyperplasia of the adipose tissue normally present in the renal sinus, and this hyperplasia is not the cause of renal atrophy or destruction but is a secondary phenomenon, which of itself is of little significance. According to the views set forth by Hamm and de Veer, designations connoting a neoplastic, invasive or destructive process should be discarded for one that clearly indicates the secondary nature of the process, and the latter should be used only to amplify the description of the pathologic lesion to which it is secondary. Of the many descriptive terms suggested the most apt seems to be "fatty replacement," employed, for example, as in "pyelonephritis with renal atrophy and fatty replacement."

Atrophic Pyelonephritis.—Lieberthal [21] stated that pyelonephritic contracture of the kidney consists of shrinkage of the renal substance as a result of chronic suppuration.

Various transitions to hydronephrosis and pyonephrosis are frequently seen. The development of the condition under discussion in a pure form depends on the presence of low grade suppuration and

20. Hamm, F. C., and de Veer, J. A.: Fatty Replacement Following Renal Atrophy or Destruction, J. Urol. **41**:850-866 (June) 1939.

21. Lieberthal, F.: Pyelonephritic Contracture of the Kidney, Surg., Gynec. & Obst. **69**:159-171 (Aug.) 1939.

usually of low grade obstruction. It is, therefore, not uncommonly seen in cases of pelvic calculus. It is most frequently confused both clinically and pathologically with renal hypoplasia and is usually unilateral.

The most important diagnostic observation is that of a marked functional defect in the involved kidney. The pyelogram reveals a pelvis which is of normal size or slightly dilated. Pyelonephritic contracture occasionally is bilateral. The symptoms may then resemble those of chronic glomerulonephritis with contracture. Unilateral pyelonephritic contracture may cause hypertension, which may be relieved by nephrectomy.

Necrosis.—Larson and Bennett [22] presented 2 cases of symmetric cortical necrosis of the kidneys demonstrated at necropsy. These cases were of particular interest because the necrosis was associated not with pregnancy but with acute delirious mania and lobar pneumonia. The renal lesion in both instances was ischemic infarction, with relatively little hemorrhage within the renal cortex. Both grossly and microscopically, the necrosis resembled the white softenings so commonly seen in the brain and myocardium, in which no pathologic process in the wall of the vessel and no thrombosis can be demonstrated. The thrombus found in the renal vein in 1 case was considered to be of secondary origin. The finding of multiple petechial hemorrhages in the mucosal surfaces of the body and in the parenchyma of the brain in the first case suggest generalized functional vascular disturbance similar to that commonly observed in fatal instances of acute delirious mania.

The cortical necrosis observed in 1 instance was less marked than that in the second, which could be explained by the fact that the immediate cause of death was lobar pneumonia and not the renal lesion per se.

Infected Wounds.—Mathé [23] reported a case of overwhelming infection of a renal incision following nephropexy and sympathectomy; the infection was caused by an anaerobic streptococcus as well as by Staph. aureus. This infection resisted all forms of treatment, including compression, surgical drainage, lavage with commonly used antiseptic solutions and the local and general use of chemotherapy. The anaerobic nature of the infective organism was diagnosed by special culture. Prompt cure followed the institution of serotherapy, which consisted of establishing the patient's tissue reactivity to antigen therapy to be used later by supplying her with intramuscular injections of preformed

22. Larson, C. P., and Bennett, R. J.: Symmetrical Cortical Necrosis of the Kidneys: Report of Two Cases, West. J. Surg. **47**:481-484 (Aug.) 1939.

23. Mathé, C. P.: Diagnosis and Treatment of Secondary Anaerobic Infections of Kidney Wounds, J. Urol. **42**:488-495 (Oct.) 1939.

immune bodies contained in blood secured from donors previously immunized by a long course of injections of undenatured antigen obtained from the offending organisms. Spectacular cure followed the intradermal, subcutaneous and local injection of undenatured bacterial antigens. Anaerobic infections of renal incisions present an immunologic as well as a surgical problem, and cure is best obtained by the cooperation of the surgeon with the bacteriologist.

Selye [24] stated that experiments on the mouse indicate that testosterone propionate administered during two to three weeks causes marked enlargement of the kidneys. Histologically, such kidneys are characterized by pronounced hypertrophy of the epithelium of the proximal and distal convoluted tubules and of the epithelium lining the parietal lamina of Bowman's capsules.

ADRENAL TUMOR

Tenenbaum [25] reported a case of cortical carcinoma with operative recovery of the patient, although sixteen months after operation many of the symptoms had returned, suggesting recurrence of the tumor.

He stated that the risk of mortality in adrenocortical carcinoma is known to be high, especially in cases in which the metabolic type of the adrenocortical syndrome is in evidence. The stormy postoperative course of his patient is an illustration of the severe reaction following removal of the tumor. Fortunately, malignant tumors of the cortex, probably as a result of their more rapid growth, seem to affect the opposite adrenal cortex much less than do the benign hyperplasias and, as a rule, cause little or no atrophy. In addition, administration of sodium chloride and extract of adrenal cortex either routinely (immediately before and after operation) or at the first indication, has been of great assistance in the prevention of acute adrenal shock and in reducing the surgical risk of adrenalectomy.

The significance of intravenous urography in the differential diagnosis of adrenal tumor has been stressed and characteristic changes in the upper calix have been described, which seem to offer a new pyelographic sign in the diagnosis of some of the tumors.

URETER

Transplantation.—Riba [26] stated that the performance of a ureterocolonic plastic operation in the presence of infection or in a potentially

24. Selye, H.: The Effect of Testosterone on the Kidney, J. Urol. **42**:637-641 (Oct.) 1939.

25. Tenenbaum, J.: Carcinoma of the Adrenal Cortex, J. Urol. **42**:277-287 (Sept.) 1939.

26. Riba, L. W.: Ureteral Transplantations: An Experimental Study, J. Urol. **42**:27-34 (July) 1939.

infected field may lead to immediate serious sepsis or result in a late, poorly functioning anastomosis.

Use of the intact ureter permits a uniform safe attachment to the mucosa of the bowel, by primary healing. The chances for the development of an ascending infection after the first stage of the operation are minimal.

The problem is to obtain a permanent functioning fistula following the second procedure. A lateral anastomosis is likely to be followed by stenosis. Excision of a piece of mucosa during the second stage, plus a more careful approximation of the ureteral mucosa to the mucosa of the bowel, has given the best results experimentally. An excessive portion of free ureter projecting into the lumen of the bowel may predispose to infection and constriction of the new ureteral orifice.

Immediate surgical survival gives no assurance that late complications and fatalities may not occur. Statistical data on final results and fatalities are incomplete.

New operative technics should first be thoroughly investigated experimentally. At least one year's postoperative observation seems necessary for evaluation of a new procedure.

Wade [27] discussed the conditions for which he has found it necessary to perform the operation of vesical exclusion or deviation of the urinary stream. They include exstrophy of the bladder, subsymphysial vesical exstrophy or epispadias in the female, vesicovaginal fistulas arising from obstetric or surgical injury or from the use of radium, carcinoma and chronic vesical tuberculosis.

The simplest and safest procedure is to transplant the ureters onto the loins. Despite the disadvantages of continuous urinary drainage onto the surface of the body, this operation is still justified in the presence of advanced malignant disease in which the situation is desperate.

The standard procedure, however, is to transplant the ureter into the colon and rectum, thereby establishing a cloaca. In certain animals in which a cloaca exists naturally, it is noted that, even though the channel is common, portions of it serve separate functions, one portion being the urodeum, in which the urine is collected, and one portion being the proctodeum, in which the intestinal contents gather. In the human being whose ureters are transplanted to the pelvic portion of the colon, it is found that comparatively soon a urodeum and proctodeum develop, as can be demonstrated by excretory urography.

Wade reported that he uses the Coffey-Mayo technic, by means of which bilateral simultaneous implantation is done in all cases, made possible by the use of intravenous infusions of isotonic solution of

27. Wade, H.: The Expectancy of Life After Ureteral Transplantation, Edinburgh M. J. **46**:61-82 (Feb.) 1939.

sodium sulfate. This procedure promotes immediate renal secretion and profuse diuresis and prevents anuria, which might otherwise result from the obstructive edema at the site of the anastomoses.

Wade considered important in postoperative management (1) the use of a rectal tube continuously to prevent the accumulation of urine in the rectum and to prevent the passage of flatus, (2) intravenous infusions of isotonic solution of sodium sulfate and (3) small doses of solution of posterior pituitary (0.25 cc.) every six hours for overdistention of the bowel.

Sufficient time has elapsed since the use of this operation to estimate its effect on the expectancy of life. For this purpose it is necessary to select patients having had this operation who were in sound general health and free from disease but who by developmental error or accident have suffered irreparable damage to the urinary bladder.

Patients who have exstrophy of the bladder are in this category. Wade reviewed the history of 4 patients who had this condition who were operated on, respectively, thirty, twenty-eight, twelve and eleven years ago. They were all well and leading healthy useful lives at the time of writing. Under these circumstances, the operation of ureteral transplantation is a relatively safe procedure and fully warranted as a method of treatment for such distressing disabilities. The high mortality which follows the procedure at times, especially in the presence of carcinoma of the bladder, is the result of the primary disease and not of any inherent disadvantages of the transplantation itself.

This fact is illustrated by Wade's statistics, which include the end results in 60 cases. The ureters were transplanted to the loin in 5 instances (eleven and twelve years ago), to a fistula in 1 and to the bowel in 54 (two stages, 14; one stage, 30; with a single kidney, 10).

The results in the whole series were as follows:

	Cases	Recoveries	Deaths
Nonmalignant conditions	27	20	7 (25.9%)
Carcinoma	33	16	17 (51.5%)
Total	60	36	24

Since January 1936, the results have improved, as is shown by the following tabulation:

	Cases	Recoveries	Deaths
Nonmalignant conditions	11	10	1* (9%)
Carcinoma	14	8	6 (43%)
Total	25	18	7

* Cervical carcinoma treated by radium with the formation of fistulas from the vagina into the bladder and rectum.

The high ultimate mortality in cases of vesical carcinoma is brought out by the statistics in the table, which include those on patients who died many months or years after the operation from the natural progress of their primary disease.

Wade concluded that when the urinary bladder has been so seriously damaged as to be incapable of repair the creation of a cloaca by transplantation of the ureters into the pelvic colon is indicated. The risk to life is not undue, and the expectancy of life is good.

Obstruction.—Campbell [28] discussed the important ureteral obstructions which occur among children; the majority of such obstructions are congenital. Persistent pyuria and pain in the loin are the two most common primary symptoms. Gastrointestinal disturbances will be noted in approximately a fourth of the cases of unilateral obstruction and in more than half of the cases of bilateral obstruction. In most instances a thorough urologic examination will readily determine the correct diagnosis. The indications for urologic examination have been stated. It is important to impress on pediatricians and other practitioners (1) that children endure these instrumental investigations far better and with

Analytic Results

	Cases	Post-operative Mortality	Ultimate Mortality	Survival *
Vesical carcinoma	27	13	23	4
Vesicovaginal fistula (obstetric injury)	9	0	0	9
Vesicovaginal fistula (radium burn)	3	2	2	1
Persistent vesical systole (tuberculosis)	6	2	4	2
Congenital abnormality	6	2	2	4
Urethral carcinoma	4	2	3	1
Intractable cystitis	3	0	0	3
Urethral stricture	2	2	2	0
Urethral fistula	1	1	1	0

* To the time of writing.

fewer reactions than do their elders, (2) that cystoscopic reactions occur less often among the young and (3) that fear of an untoward reaction alone never should be considered a contraindication to urologic investigation for a child. Treatment in such cases usually can be conservative, and the patient should be given the benefit of conservatism so far as is compatible with good surgical judgment. In many instances advanced disease of the upper portion of the urinary tract consequent to the obstruction or the complicating infection will require radical surgical attack and frequently loss of the kidney. Campbell stated also that proper surgical attention to the child preoperatively, in the operating room and postoperatively will be rewarded by satisfactory results and a surprisingly low mortality.

Rudnick and Cornell [29] reported 38 cases of ureteral pain in which stricture of the ureter was demonstrated in 34, and ureteritis in 31.

28. Campbell, M. F.: Ureteral Obstruction in Children, J. Urol. **41**:660-678 (May) 1939.

29. Rudnick, D. F., and Cornell, E. L.: Clinical Manifestations of Stricture of the Ureter in Women, J. Urol. **41**:679-686 (May) 1939.

Abdominal or lumbar pain or discomfort is the prominent symptom. The symptoms are frequently periodic and often associated with menstruation. Vesical symptoms are not prominent.

The diagnosis is easily made by vaginal palpation of the ureters, which are always tender. In many instances the pain of which the patients complain can thus be reproduced by the physician.

The urologist must not be content with being able to pass a no. 5-F catheter to rule out a stricture. Number 7 or no. 8 bulb-tipped catheters are preferable. The average dilatation should be to the diameter of a no. 10-F catheter. In 75 per cent of the cases one dilation suffices.

Passage of the ureteral catheter reproduced accurately the "ureteral pain" of which the patient complained in all but 3 cases.

Ureterocele.—Huth [30] reported a case of ureterocele in which the ureter extruded from the bladder. The patient was a woman aged 27. When she was a child, a mass had suddenly protruded from the urethra and had been replaced. Two years previously she had experienced severe pain on vomiting and had felt that something was forcing itself through the neck of the bladder. On examination she had found a small, red, painful mass at the urinary meatus.

Cystoscopic examination demonstrated low grade cystitis. A smooth, round mass about the size of a hen's egg was seen in the left half of the bladder. The termination of this contour below was at the site of the left ureteral opening, where a narrow pedicle communicated with the mass, which was identified as an enormously dilated ureter. The wall was soft and permitted indentations by the ureteral catheter. The apex of the mass was red and apparently inflamed, probably because of repeated exposure through the urethral opening. A contrast medium was injected intravenously, and in twenty minutes a urogram showed the right kidney to be normal in size, shape and position and to be concentrating the dye in a normal manner. There was no dilatation of either the pelvis or the ureter, the orifice of which was normal. The left kidney was much enlarged. The left ureter was considerably enlarged. The ureterocele was shown by a large, normal shadow in the cystogram. At the ureteropelvic juncture there seemed to be a kink or obstruction, but there was little pyelectasis.

With the patient under ether anesthesia, the right ureter was dilated with the Neil Moore fin bougie and cut with a short wave cutting current. Later, the left ureter was fulgurated, which destroyed a large portion of the superior circumference. In neither operation was any bleeding experienced, and the patient had no shock. Recovery was uneventful.

30. Huth, P. E.: A Large Ureterocele Which Extruded from Female Bladder on Voiding, J. Urol. **42**:534-537 (Oct.) 1939.

Later, cystoscopic examination showed a large ureteral orifice on the left side. A cystogram, made with sodium iodide, showed reflux up the left ureter, but the ureter was much smaller than it had been before operation, and the kidney had assumed its normal contour. The right kidney and ureter appeared normal, and the bladder was normal.

One year later, the patient did not complain of any symptoms. Indigo carmine injected intravenously was eliminated from the right kidney in eight and one-half minutes and from the left kidney in three and one-half minutes. The general health of the patient was excellent.

BLADDER

Beer [31] discussed the surgical treatment of infiltrating carcinoma of the bladder.

In cases in which the tumor and the involved wall of the bladder can be excised, this type of operative treatment, often involving reimplantation of the ureter, gives the best results. With some of the more extensive growths total cystectomy, if feasible, gives surprisingly good results judged by five year cures. With other more or less extensive growth radon seeds may have to be introduced, by means of cystotomy or through a cystoscope. This is always a hit or miss affair, because the surgeon cannot accurately delimit the extent of the infiltrative process by sight or by palpation from within the bladder. Despite these handicaps, a small percentage of patients so treated seem to be definitely cured. The end results, however, are far inferior to those obtained in cases in which the lesion is resectable.

Urologists who have had an extensive series of patients (in Beer's clinic almost 700 patients have been treated) gradually have come to a better understanding of the problem involved, and it is most encouraging to see that the last report of the Registry, in 1936, confirms Beer's conclusions that surgical excision and resection give the best end results.

In his own experience Beer has found that there are, on the one hand, benign papillomas and, on the other, two types of carcinoma: (1 *a*) papillary carcinoma with atypical cells, plus invasion of the stroma and occasional thrombi of the lymph vessels; (1 *b*) papillary tumors with these characteristics plus an infiltration and invasion of the wall of the bladder to varying depths, and (2) more or less solid, more or less nodular, infiltrating carcinoma extending well into the wall of the bladder and occasionally extending widely in a horizontal direction.

In a recent review by Beer on total cystectomy, it was found that the more radical the surgical treatment the higher the percentage of

31. Beer, E.: The Surgical Treatment of Infiltrating Carcinoma of the Bladder, Surg., Gynec. & Obst. **69**:113-114 (July) 1939.

five year cures. In a series of 24 malignant tumors of the bladder for which total cystectomy had been performed, 6 patients died after the operation. Of the 11 patients operated on up to five years ago, 2 died, the deaths being classified as operative. Among the other 9 patients, who survived the operation, those who survived for five years or more constituted 55 per cent of the whole group. In 88 cases of carcinoma of the bladder, papillary and infiltrating, Beer had 15 operative deaths. Sixty-five patients could be followed to test the value of the therapy, and 24 were cured for five years.

In closing, Beer emphasized the importance of learning the technic of partial cystectomy, with or without ureteral reimplantation, as well as the technic of total cystectomy with implantation of the ureters in the skin or in the bowel, because all other methods of approaching this most difficult problem are hit or miss procedures.

Darget and Lange [32] reported the results of treatment of tumors of the bladder by implantation of radium needles, with a statistical study of 60 cases. Thirty patients were still alive at the time of writing. The immediate mortality was 3.3 per cent. Four other patients died in the following two months. Thirty-two patients lived more than five years. Of these, Darget and Lange considered 14 completely cured.

Colby [33] reported a group of malignant tumors of the bladder in which the patients were treated by supervoltage roentgen irradiation with a recently devised million volt generator. Although the series is entirely inadequate as a basis on which to evaluate fairly this form of treatment, certain tumors appear to be profoundly affected, with considerable regression. Those portions of the tumor which project into the cavity of the bladder seem to be affected considerably more than those which have extended through the wall of the bladder. Other tumors are affected little, if any, and are considered "radioresistant." It is not considered that supervoltage irradiation, in its present state, takes the place of operation in instances of circumscribed cancer which can be adequately removed. The doses so far employed are probably considerably less than it is possible to use, but more experience is necessary to standardize the dosage and to determine the ultimate effect. The local and general untoward reaction of the tumors is less than with lower voltages and the regression more evident.

De Waard [34] reported 2 cases of tumor of the urachus.

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32. Darget, R., and Lange, J.: Résultats du traitement des cancers de la vessie par l'implantation d'aiguilles de radium à vessie ouverte en un temps (statistique intégrale actuelle), J. d'urol. **47**:273-286 (April) 1939.

33. Colby, F. H.: Super-Voltage Radiation in the Treatment of Bladder Tumors, J. Urol. **42**:538-553 (Oct.) 1939.

34. De Waard, T.: Two Rare Cases of Bladder Tumor (Urachus Tumor), J. Urol. **42**:554-558 (Oct.) 1939.

In 1 case the patient was a woman aged 54 who had been experiencing recurring vesical trouble. Cystoscopic examination revealed diffuse cystitis. In the median line, in the upper part of the bladder, a slight, clearly outlined swelling could be noticed, in the center of which a tuft of fibers, such as were floating in the urine, could be made out protruding into the cavity of the bladder. A ureteral sound could be introduced about 2 cm. through these fibers into what was, apparently, an existing duct or cavity. The urine from both kidneys was completely normal. The bladder was filled and the peritoneum was opened by suprapubic incision. A tumor the size of a mandarin was found in the wall of the bladder. The peritoneum had grown firmly to this in the place in which the peritoneal fold usually is found. It was impossible to remove the peritoneal covering; so an incision was made around it, and the abdominal cavity was opened. The tumor was found attached to a thick string of omentum which stretched in the direction of the gallbladder. This string was cut through, and the tumor was extraperitonealized. It was removed from the wall of the bladder, and the bladder was closed. A good result was obtained.

In the second case the patient was a 37 year old man who complained only of occasional pain in the lower portion of the abdomen. Cystoscopic examination demonstrated a small growth resembling a papilloma in the upper part of the bladder, which bled occasionally for several months. At a second cystoscopic examination a granulating defect was found in the region of the papillary growth. Operation, similar to that in the previous case, revealed a similar-sized tumor, which also could not be separated from the peritoneum. The tumor was removed.

At cystoscopic examination both the tumors were found to be covered with mucosa. In the first case there was a duct about 2 cm. in depth, and in the second there was a small suggestion of a similar duct. The diagnosis in the second case was colloid carcinoma.

Ulcer.—Kretschmer [35] reported 138 cases of elusive ulcer of the bladder. There seems to be a prevailing opinion among some urologists that patients having this condition are never cured and that they must bear their condition until death. Not all urologists, however, share this point of view. In a recent article Crenshaw stated "that the end-results are better than they are generally believed to be"; he found that 72 per cent of his patients stated that they were improved or cured, 59 per cent that they were greatly improved or cured and 40 per cent that they were cured. Grenshaw stated also that resection should be done more frequently than it is at the present time, in suitable instances.

35. Kretschmer, H. L.: Elusive Ulcer of the Bladder: A Report of One Hundred and Thirty-Eight Cases, J. Urol. **42**:385-395 (Sept.) 1939.

In Kretschmer's series of cases the youngest patient was 20, and the oldest was 81. One hundred and nineteen of the patients were women, and 19 were men.

Some of the most striking results have been obtained in so-called early instances of the disease. Therefore, Kretschmer stressed the importance of obtaining a careful history and of bearing in mind the possibility that a patient experiencing frequent and painful urination may have an elusive ulcer. Frequency of urination was present in every instance. Generally mild at the onset of the disease, it is often temporarily relieved, but the disease is progressive, and urinary frequency, as well as pain on urination increases.

There is no standard treatment for elusive ulcer. Wide resection of the ulcer-bearing region has been practically discarded because of the relatively large number of recurrences. Among Kretschmer's patients, the condition recurred in 40 per cent. In his experience high voltage roentgen therapy has not been of any value, whether used alone or in combination with fulguration. Presacral neurectomy was without beneficial result. In some instances the use of a 2 per cent solution of silver nitrate with fulguration was apparently of some value.

The treatment most frequently employed is fulguration through the cystoscope; this generally is looked on as simple and safe. Frequently it is combined with dilation of the bladder by water.

In Kretschmer's series of 138 cases 105 were available for study, with the following results: patients cured, 20.37 per cent; greatly improved, 36.11 per cent; improved, 13.88 per cent and unchanged, 29.63 per cent.

Exstrophy.—Russell [36] described a case of complicated exstrophy of the bladder in which the condition differed from the usual complicated ectopia vesicae in that (1) an anterior wall of the bladder was present but no "roof," (2) there was only one bowel, opening at the ileocecal region, (3) there were two vermiform appendixes, (4) there was almost complete absence of the large intestine, (5) there was no evidence of external genitalia, (6) sacral meningocele occulta was present and (7) marked cystic swelling of the caudal end of the neurenteric canal was present.

The baby was a well formed full term infant whose weight at birth was 6½ pounds (2,948 Gm.) and who lived eleven days. There were no abnormalities of the head, neck, thorax or extremities.

Russell gave a detailed description, both gross and histologic, of the abnormal structures present and concluded that the case supports the Wood-Jones mechanical theory of the origin of exstrophy of the

36. Russell, K. F.: A Case of Complicated Exstrophy of the Bladder Presenting Many Unusual Features, Brit. J. Urol. **11**:31-47 (March) 1939.

bladder. This theory postulates that at some stage in embryonic development overdistention of the bladder occurred with subsequent bursting of the anterior wall.

In its support Wood-Jones contended (1) that urine is secreted by the fetus in utero and when a child is born who has an imperforate urethra all stages of vesical distention can be seen, (2) that cases of ectopia vesicae have been recorded in which occlusion of the cleft urethra was present and (3) that overdistention of systems other than the urinary system is seen in the presence of hydrocephalus and syringomyelocele. He postulated that distention of the bladder is to ectopia vesicae what hydrocephalus is to anencephalia, or syringomyelocele is to spina bifida.

The mechanical theory also would account for the wide separation of the pubic bones and the lateral rotation of the ilium and ischium, which are characteristic of the condition.

There are several constant observations in the presence of complicated exstrophy which cannot be explained by a given theory and which are difficult to understand; namely, the fact that all patients suffering from complicated exstrophy have two vermiform appendixes, whereas those suffering from simple exstrophy possess only one, and that the ileocecal region is the site of the openings of the bowel on the cloaca and two openings are present, one for the small bowel and one for the large bowel.

Postoperative Care.—Many chronic and serious lesions of the urinary tract have their origin in the postoperative care of the bladder, especially following gynecologic operations. The danger lies not so much in catheterization as in urinary stagnation, because simple catheterization at times other than in the postoperative period is relatively harmless.

After vaginal and pelvic operations near the region of the bladder there is practically always residual urine. When the patient has been catheterized and bacteria introduced, it becomes important to prevent stasis of residual urine on resumption of voiding. Intermittent catheterization, to this end, until the residuum is negligible will reduce the incidence of infections of the urinary tract.

The ideal procedure is one which will do away with catheterization entirely, if possible. Most reports on methods of promoting voiding are concerned with inducing the bladder to empty itself after postoperative retention has occurred. These methods include the use of solution of posterior pituitary and of the parasympathetic stimulators, such as carbaminoylcholine hydrochloride and acetylbetamethylcholine hydrochloride and the injection of an irritant, such as a 2 per cent solution of boroglycerin or several ounces of air, into the full bladder. The

administration of acetylbetamethylcholine hydrochloride by mouth in doses of 25 mg. is at times beneficial and is not associated with serious constitutional effects. However, hypodermic administration is dangerous and is accompanied by alarming constitutional effects, such as profuse sweating, salivation, fainting, involuntary micturition and defecation and marked decrease in blood pressure, and in 1 reported instance resulted in death.

Woodruff and Te Linde [37] reported a method which is aimed at prevention of distention by inducing the patient to void early and thus to reduce the necessity for catheterization. They instil 1 ounce (29.57 cc.) of a 0.5 per cent aqueous solution of the disodium salt of 2:7-dibromo-4-hydroxymercurifluorescein (mercurochrome) into the bladder at the conclusion of the operation and at the same time instil into the rectum 1 liter of a 2 per cent solution of sodium bicarbonate containing 60 cc. of liquid petrolatum. Studies showed that although the latter procedure did not aid voluntary micturition, it provided a good intake of alkaline fluid during the early postoperative period and facilitated early defecation.

Among 500 patients who had undergone pelvic laparotomy, the instillation of mercurochrome into the bladder reduced the incidence of catheterization to 6.5 per cent as compared with 51 per cent in a control series of patients who did not receive such instillation. The patients for whom the instillation was used voided earlier and in greater amounts, thus more completely emptying the bladder, than the patients in the control series. Postoperative infection of the urinary tract did not occur among any of the 500 patients who had undergone laparotomy except 3, each of whom had presented a definite history of infection of the urinary tract preoperatively.

This procedure is of no value with extensive plastic operations on the vagina. In such instances an indwelling male catheter should be used for the first week, and then catheterization should be used until residual urine no longer exists.

Changes During Pregnancy.—Muellner [38] discussed the physiologic changes in the bladder occurring during pregnancy and the puerperium. He stated that during this period the bladder undergoes progressive changes in tone and capacity.

Beginning with the third month of gestation there is a gradual increase of vesical capacity and decrease in vesical tone, reaching extreme levels in the last trimester. The tone improves before the

37. Woodruff, J. D., and Te Linde, R. W.: The Postoperative Care of the Urinary Bladder, J. A. M. A. **113**:1451-1454 (Oct. 14) 1939.

38. Muellner, S. R.: Physiological Bladder Changes During Pregnancy and the Puerperium, J. Urol. **41**:691-695 (May) 1939.

termination of pregnancy. The bladder empties without residual urine during pregnancy. Post partum, the bladder capacity is likely to be largest, and there is considerable decrease in tone as compared with that of the ninth month. Residual urine is common, and its amount may be large during this period, and it should be drained by catheter if infected. The bladder returns to normal during six to eight weeks.

PROSTATE

Hypertrophy.—Thompson [39] presented a case in which transurethral resection was performed in the presence of marked renal insufficiency. The patient was a man aged 52 who had 650 cc. of residual urine. The results of a study of the chemical picture of the blood were as follows: urea, 488 mg. per hundred cubic centimeters, and creatinine, 15.2 mg. On the twenty-third day after his admission to the hospital, the urea content of the patient's blood was 124 mg. per hundred cubic centimeters, and transurethral resection was performed, 19 Gm. of prostatic tissue being removed. The patient was dismissed from the hospital on the fourteenth postoperative day, or thirty-six days after his admission. There was no residual urine at the time of dismissal.

Habein [40] stated that certain factors have a distinct relation to the outcome of operation for obstruction of the vesical neck, especially because of the age of patients who have prostatic hyperplasia. Some of these factors are (1) the general condition of the patient, (2) renal function and cardiovascular reserve, (3) appropriate preoperative and postoperative management and (4) the time, type and extent of operation.

The "surgical" diseases of the kidney frequently caused by urinary obstruction and infection are entirely different in causation, pathologic aspects, treatment and prognosis, from the so-called medical diseases of the kidney, generally classified as "glomerular nephritis."

In the improvement and management of renal function, certain factors are emphasized, such as (1) drainage, (2) amount and types of fluids administered and (3) "extrarenal" factors in renal function.

Carcinoma.—Hinman and Smith [41] stated that radical surgical treatment is the only method which will cure carcinoma of the prostate. A decade ago, radium was used vigorously in the treatment of 14 patients,

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39. Thompson, G. J.: Transurethral Resection in the Presence of Marked Renal Insufficiency: Report of a Case, Proc. Staff Meet., Mayo Clin. **14**:401-404 (June 28) 1939.

40. Habein, H. C.: Obstruction in the Neck of the Bladder: Criteria of Operability, J. Urol. **42**:581-601 (Oct.) 1939.

41. Hinman, F., and Smith, D.: Carcinoma of the Prostate, California & West. Med. **51**:235-241 (Oct.) 1939.

and more recently, with the advent of high voltage roentgen rays, the latter form of radiation was tried hopefully. Aside from relief of pain for some patients and possibly a slight prolongation of life, the results were most discouraging.

Only 3 of the 24 patients reported on by Hinman and Smith who had transurethral resection to relieve obstruction were alive at the time of writing; none have been alive longer than two years. Three had been treated for prostatism by suprapubic prostatectomy. Twenty-one were dead at the time of writing; all of these had died within three years after operation and most of them within one year; all died of carcinoma.

It is difficult to estimate the value, if any, of conservative prostatectomy, such as the perineal enucleation of hyperplastic tissue which is causing obstruction, without making an attempt to remove any of the carcinoma associated with it. The operation is purely palliative; it is an effort to relieve urinary distress and, in this sense, is comparable to transurethral resection. Of 58 patients thus treated in the series reported by Hinman and Smith, carcinoma had not been suspected before operation in 9, although the lesion was too far advanced to permit radical removal. Thirty-three patients were treated by the implantation of radon seeds, each from 1 to 3 millicuries in capacity, at intervals of 1 cm. throughout the carcinomatous region at the time of operation. One of these patients lived four years, 1 five years and 1 seven years, but all died of carcinomatosis. More recently 5 others received intensive high voltage roentgen therapy, but none survived two years. One other patient, who did not receive irradiation, survived six years but died of recurrence. With these 4 exceptions, no patient lived longer than two years, and 29 died within a year.

In treating 20 patients listed as having had partial radical prostatectomy, it was found impossible, on attempting radical operation, to remove all the carcinoma because it had extended beyond the vesicles, either too far up the vas or into the bladder. Nine died of carcinoma within two years. One lived five years; 6 had lived less than two years at the time of writing. None was cured, but generally the patients have been more comfortable than the run of patients in either of the two groups previously mentioned.

For 21 of the 156 patients reported on by Hinman and Smith radical prostatectomy was possible. It was felt that all local portions of carcinoma had been removed at operation. Before operation none showed any clinical evidence of metastases. The seminal vesicles of 11 patients were invaded, however. Three patients died shortly after operation: 1 of pulmonary embolism, 1 of paralytic ileus and 1 of pneumonia. Six died afterward, having carcinoma at the time of death. Seven died with

no evidence of carcinoma, 3 of senility, 1 eight years and 2 seven years afterward. Five were living at the time of writing with no clinical evidence of carcinoma: 1 for seven years, 1 for two years and 3 less than one year. All had good control and no urinary complaint. On a conservative basis, the aforementioned figures indicate the cure of half of those treated radically.

Patients who clinically display evidence of having carcinoma so far advanced as to be incurable but who have no enlargement or urinary obstruction associated therewith may be left untreated, or else irradiation may be used when they suffer pain from pressure or extension.

Patients who have median bars and incurable carcinoma may be relieved temporarily by resection, but if severe infection or calcification is present radical prostatoseminal vesiculectomy will give the greatest, most enduring relief, and life may be prolonged by embedding radium in the local regions of carcinoma which are left.

Patients who have hyperplasia and incurable carcinoma may be treated by conservative prostatectomy supplemented by the full use of irradiation.

Belt [42] reported that after careful physical examination of 25 patients he decided that the growth could be completely circumscribed by the radical perineal operation. For 18 of these, a close inspection of the specimen revealed the presence of carcinoma and showed the growth to be confined within the specimen. Ten of these 18 patients were living and well at the time of writing, after periods varying from three months to nine years. In 7 of the group of 25 patients, the carcinoma had extended to the cut edge of the part removed and, therefore, probably beyond it. The patients received massive high voltage roentgen therapy. Five were living and well at the time of writing, after periods varying from one to three years. One died of metastases after five years and one of the same cause after four years.

Eighty-eight of Belt's patients suffering from prostatic carcinoma were afforded relief from the obstruction of the vesical neck through electrosurgical resection. Forty-eight had metastases when they were first encountered. Forty had no demonstrable metastases and received vigorous high voltage roentgen therapy in the hope that growth would be arrested. Of the groups submitted to resection, those having had resection and high voltage roentgen therapy and those untreated except by resection to relieve obstruction were about equal in respect to length of life from the date of the onset of symptoms, but the patients who received roentgen therapy were in less pain and looked healthier than the others at the time of writing.

42. Belt, E., in discussion on Hinman and Smith.[41]

Bumpus [43] stated that carcinoma of the prostate gland cannot be accurately compared with other forms of malignant growth because of its late occurrence. That patients who have a malignant growth of the prostate have the shortest expectancy of life of any patients suffering from malignant disease is certain to influence therapy. It is one thing to tell a person in the early forties, who has an expectancy of life of several decades, that radical surgical treatment has the possibility of curing him although it is accompanied with great risk, but it is another matter to inform the patriarch of 75, who has an expectancy of less than a decade, that he should risk a major radical procedure involving a high risk of mortality for the remote possibility of a cure.

Such advice is still further weakened by the fact that carcinoma of the prostate gland, unlike other malignant diseases, not only occurs late in life but is one of the slowest growing of all types of malignant disease. Numerous instances are on record of patients suffering from carcinoma of the prostate gland, proved by biopsy, who have lived for more than five years with no other form of treatment than relief of urinary obstruction, and several instances are recorded of patients who have survived for more than a decade. It is the slow growth of carcinoma of the prostate gland which has led to such confusion concerning its treatment.

In most malignant diseases, the number of three year controls is given as a criterion of the success or failure of treatment. Carcinoma of the prostate gland, when untreated, has an average duration of more than three years. Bumpus once traced 171 patients from the time of the occurrence of their first symptoms to death, and found that the average duration of life for them was three and one-quarter years.

Robinson, Gutman and Gutman [44] recorded the serum phosphatase activity at p_H 4.9 and at p_H 8.6 of 19 patients who had prostatic carcinoma with skeletal metastases. The "acid" phosphatase activity of the serum was found to exceed 3.0 units per hundred cubic centimeters in 16 of the 19 patients. Thirteen patients who had prostatic carcinoma *without* roentgenographically demonstrable metastases to bone and 6 who had benign prostatic hypertrophy were found to have serum "acid" phosphatase values within normal limits. Of the control series of more than 250 patients, those who had advanced Paget's disease and high serum "alkaline" phosphatase values showed some increase in serum phosphatase activity at p_H 4.9, but all patients who had early and moderately advanced Paget's disease had normal serum "acid" phosphatase values.

43. Bumpus, H. C., Jr., in discussion on Hinman and Smith.[41]

44. Robinson, J. N.; Gutman, E. B., and Gutman, A. B.: Clinical Significance of Increased Serum "Acid" Phosphatase in Patients with Bone Metastases Secondary to Prostatic Carcinoma, J. Urol. **42**:602-618 (Oct.) 1939.

From their experience and from the reports in the literature (44 cases in all), Robinson, Gutman and Gutman felt justified in concluding that increased serum "acid" phosphatase activity is consistent and specific enough in occurrence to be helpful in the differential diagnosis of prostatic carcinoma with skeletal metastases. The determination of serum "acid" phosphatase activity appears to be a useful supplement to the clinical and roentgenographic study of patients who have prostatic carcinoma, particularly if surgical procedures are contemplated. As regards prognosis, the presence of increased serum "acid" phosphatase activity in patients who have prostatic carcinoma implies dissemination of the primary tumor and in this sense has an unfavorable significance; an upward trend in serum "acid" phosphatase values may signify further metastatic involvement.

URETHRA

Carcinoma.—Wishard and Bodner [45] reported a case of squamous cell carcinoma of the anterior portion of the urethra cured by amputation of the penis and postoperative irradiation. Approximately 125 cases of primary carcinoma of the male urethra are on record. The deep portion of the urethra is a little more often the seat of the lesion than is the anterior portion.

Causative factors include old age, predisposition, chronic irritation, infection, inflammation, stricture, trauma and benign papillomas.

Symptoms are produced by narrowing of the urethral lumen, formation of tumor and secondary infection with development of abscesses and fistulas.

The histologic structure of urethral carcinoma usually is that of squamous cell carcinoma. Other types are discussed. Metastases occur through the lymphatic system to the regional lymph nodes.

The prognosis is usually poor but would be better if patients could be treated earlier.

Treatment consists of early diagnosis, surgical intervention and high voltage irradiation. More frequent urethroscopic examination and biopsy for patients supposed to have irretractable strictures and periurethral abscesses which fail to improve would render the outlook more hopeful than it is now and would increase the number of cases reported as well as detect instances of the disease earlier.

The female urethra and vesical trigon [46] frequently are the seat of inflammatory lesions which give rise to the symptom complex of

45. Wishard, W. N., Jr., and Bodner, H.: Primary Carcinoma of the Male Urethra, J. Urol. **42**:35-46 (July) 1939.

46. MacKenzie, D. W., and Seng, M. I.: Common Conditions of the Neck of the Female Bladder and Urethra, Canad. M. A. J. **40**:428-432 (May) 1939.

increased frequency of urination, urgency, tenesmus, dysuria, urethral pain and hematuria, as well as the so-called bladder trouble, one of the most common disorders of women.

Inflammatory lesions give rise to changes in tissue recognized as (1) trigonitis, (2) trigonitis cystica, (3) trigonitis pseudomembranosa, (4) chronic inflammatory nonspecific urethritis, (5) urethritis cystica, (6) stricture of the urethra, (7) caruncle of the urethra, (8) relaxation of the urethral sphincter, causing incontinence and (9) urinary fistula.

In order to correlate the clinical with the pathologic picture, the histopathologic aspects of the vesical outlet and the urethra in the female were studied in 50 specimens obtained at necropsy.

In the child two types of vesical neck and urethra were found. The most frequent observation was smooth mucosa without any invagination or perimucosal structures. The second normal type was a urethra which had mucosal invaginations situated just distal to the vesical orifice. These invaginations are exaggerated by relaxation of the surrounding structures. In the anterior third of the urethra, periurethral tubular structures distinct from Skene's glands are seen. They are absent in the inner third. Glandular cells, distinct from normal transitional cells, surrounding a small lumen and manifesting a definite secretory appearance, are found within the epithelial lining of the vesical neck of the urethra, of the urethral crypts and invaginations and of Skene's ducts.

In the adult patient the most striking observation was the almost universal presence of submucosal infections indicated by infiltration of round cells and other evidences of inflammation. There was proliferation of surface epithelium with cell nests and cell bud, cysts and fibrosis.

The changes are the result of repeated trauma caused by sexual cohabitation and childbearing and infection caused by those organisms which are continuously present about the external genitalia of the adult.

Clinical evidences of these changes are intermittent attacks of increased frequency of urination associated in the more severe phases of the condition with terminal tenesmus, a sensation of incomplete emptying of the bladder and, at times, hematuria. Vague indefinite pains arise in the urethra, or general pelvic discomfort referred to the back or into the thighs is present.

On urethral calibration with a sound or bougie à boule, infiltrations or at times even true strictures or a general contraction are found. Bleeding may occur after gentle and careful instrumentation. On cystourethroscopic examination, granulation of the urethra and trigon, pedunculated cysts or sessile polyps and at times the characteristic changes of pseudomembranous trigonitis are seen.

In the acute phase of these infections the treatment consists in (1) forced administration of fluids, (2) heat in the form of vaginal douches and sitz baths, (3) sedative rectal suppositories, (4) mild silver salts instilled into the bladder and (5) alkalis or urinary antiseptics given by mouth as indicated.

In the chronic phase, if a granular change predominates, stimulating applications, such as silver nitrate, are indicated. If the lesions are cystic, they should be destroyed by cauterization or electrocoagulation; if they are fibrotic, dilations are indicated.

For all lesions the basis of treatment is dilations of high degree.

TESTES

Hypertrophy.—Zide [47] stated that a comparison of the size of a series of normal adult testes with the larger or remaining testis in a group of cases of unilateral atrophy or orchidectomy revealed essentially no difference in average measurements. The largest testis of the normal group approximately equaled in length and width the largest testis present in the abnormal group. There is no evidence on the basis of this study that the adult human testis undergoes any appreciable compensatory hypertrophy after atrophy or removal of its mate.

Tumor.—Higgins and Buchert [48] stated that malignant tumors of the testicle may be divided into the homologous and the heterologous type. The former is comprised mainly of the sarcomas and seminomas, the latter consisting of mixed tumors of adult and embryonal tissue.

There was a history of previous trauma in 19.4 per cent of the cases reported by Higgins and Buchert.

Bilateral testicular tumors are rare. Neoplastic disease seems to involve the right testicle more often than the left. There are no pathognomonic signs, painless swelling of the testis being the first symptom in the vast majority of cases.

The test for gonadotropic substance is valuable in diagnosis, prognosis and treatment.

Metastasis takes place by way of two routes, namely, lymphatic extension and dissemination through the blood stream. The majority of lesions metastasize first to the retroperitoneal lymph nodes. The lungs and supraclavicular glands also are frequent sites of metastases.

Simple castration, castration followed by roentgen or radium therapy, radical operation, Coley's toxin and roentgen or radium therapy alone, are the usual types of treatment.

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47. Zide, H. A.: Does Compensatory Hypertrophy of the Adult Human Testis Occur? J. Urol. **42**:65-67 (July) 1939.

48. Higgins, C. C., and Buchert, W. I.: Malignant Tumors of the Testicle: A Review of Eighty-Three Cases, Am. J. Surg. **43**:675-687 (March) 1939.

Results of treatment are discouraging. The best results are obtained in cases in which there is no clinical evidence of metastasis. In the series reported by Higgins and Buchert, a combination of castration and roentgen therapy seemed to give the longest survival rate.

VAS DEFERENS

Surgical Treatment.—Freiberg and Lepsky [49] reported a case of restoration of the continuity of the vas deferens.

A man, aged 33, eight years after having had vasectomy desired attempted restoration of the channel of the vas. With the patient under gas anesthesia, an incision was made in the upper half of the right side of the scrotum. The vas was isolated, and a side to side anastomosis of its upper and lower portions was made. A strand of silkworm catgut was passed through the anastomosis to keep it open until healing took place. A roentgenogram, made immediately after the operation, disclosed that both the upper and the lower portion of the vas were patent and also showed the presence of the contrast medium in the right seminal vesicle. Numerous specimens of semen obtained later showed a normal number of spermatozoa.

Perves and Duvergey [50] stated that, although normally the orifices of the ejaculatory ducts are physiologically closed and impermeable to injections or to a reflux from the urethra, in the presence of some acute infections they open wide and make such a reflux possible, from the urethra into the seminal vesicles and vasa deferentia. This gaping or opening is characteristic of all glandular orifices when infected; first they become paralyzed; then destructive lesions occur, which seem to favor a more nearly perfect drainage of the gland. There is thus a parallelism between disturbances concerning vesicorenal reflux and urethrovesiculodeferential reflux.

Perves and Duvergey demonstrated this reflux by means of retrograde urography (radiopaque oil) in 4 patients who came under their notice. It has also been demonstrable during micturition. They spoke of "passive" reflux in the former case and of "active" in the latter. In 2 of their cases the radiopaque oil entered the ejaculatory ducts but not the bladder, possibly because of obstruction at the neck of the bladder. In the other 2 some of the radiopaque oil entered the bladder and some the ejaculatory ducts.

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49. Freiberg, H. B., and Lepsky, H. O.: Restoration of the Continuity of the Vas Deferens Eight Years After Bilateral Vasectomy, J. Urol. **41**:934-940 (June) 1939.

50. Perves, J., and Duvergey, H.: Du reflux urétro-vésiculo-déférentiel, J. d'urol. **48**:97-113 (Aug.) 1939.

Sixteen cases of passive reflux have been reported in the literature in addition to the 4 herein placed on record. In 3 the vesicles alone received the reflux; in 7 the vasa deferentia alone received it, and in 4 the entire vesiculodeferential system received it. Nine patients were observed in the course of genital tuberculosis, 6 following prostatectomy and 5 during the presence of urethritis and common prostatitis. Although primary tuberculosis of the genital tract does not show any pathognomonic image in urethrographic examination, Chevassu stated the belief that in the absence of other information the urologist should regard the reflux as of tuberculous origin.

Perves and Duvergey explained the reflux as follows: In acute or subacute infections, the muscles lying beneath the inflamed mucosa have been subject to temporary atony, which becomes definite if the infection persists. The orifices, which are muscular structures, are affected by this process. It is then possible to conceive of the existence of *transient* refluxes of a *dynamic* nature or *definitive* refluxes if the infection is old.

Two factors are necessary for the production of reflux: (1) contractions of the bladder which drive the fluid into the prostatic portion of the urethra and (2) a slight obstacle situated below the verumontanum, contraction or spasm of the membranous sphincter. Then the opaque fluid, subjected to two pressures in opposite directions, forces the orifices of the more or less atonic ducts. Italian urologists, in order to obtain this reflux, fill the bladder with opaque substance and then make the patient urinate while they compress the urethra. For this active reflux to be present, no gross lesions at the verumontanum are necessary; paralysis of the urethral muscle or slight sclerosis of the verumontanum is enough. There is no proof that antiperistaltic contractions cause these refluxes; to date there has been no experimental control of this possibility. The frequency with which obstacles (strictures) of the urethra figure in the cases is striking.

Clinically, reflux is most frequently discovered during urethrographic examination. But the existence of inflammatory attacks of orchiepididymitis may lead the urologist to look for it. There is no doubt that rectal examination in instances of reflux discloses more or less disease of the prostate gland or seminal vesicles. Urethroscopic examination, on the other hand, furnishes more exact information than does rectal examination. Some authors note irregularity and abnormal rigidity of the prostatic portion of the urethra, making it difficult to insert instruments. Changes in the verumontanum are constant, as is inflammation either of the verumontanum, the ducts or the prostate gland. The orifices of the ducts are often open; sometimes the examiner can see veritable caverns that have destroyed some or all of the region of the verumontanum.

This reflux is not in itself grave; it is a symptom, and its prognosis is in strict relation to its cause. In the presence of genitourinary tuber-

culosis, it indicates rather advanced destruction; in the presence of other infections, it may diminish or disappear during the course of treatment. After prostatectomy, it causes pain only occasionally.

The present study shows that if fluid can pass into the vasa deferentia by reflux, so also may infection pass along this route, into the testis and epididymis, an observation that has been confirmed by the results of vasotomy systematically done by Marion's advice before prostatectomy. Suppression of attacks of epididymitis, formerly so frequent, by simple ligature and section of the vasa deferentia, proves the propagation of urethral pathologic agents by way of the ejaculatory ducts. As a general rule, therefore, in the presence of attacks of orchi-epididymitis, the urologist should first treat the urinary infection, making a urethroscopic examination of the region of the verumontanum and a rectal examination to determine the condition of the prostate gland and the seminal vesicles.

URINARY INFECTION

Secrétan [51] discussed the sterilizing effects of increased oxidation. He stated that the city of Paris uses oxidation to sterilize its water supply, and recent experiments have shown that it is bactericidal, especially for Bacillus coli. Secrétan tried endovesical ozone therapy in 5 instances. He used a two way catheter, so that the pressure in the bladder never increased to the point at which air embolism might occur. The immediate results were good, but a few days later as many colon bacilli were found in the urine as had been present before treatment. Secrétan concluded that ozone therapy, which is disagreeable to the patient and difficult for the physician to administer, produces no more satisfactory results than the ordinary methods of treatment.

URINARY CALCULI

Kretschmer and Brown [52] studied the records of 950 cases of peptic ulcer and of 1,260 cases of urinary calculi to determine whether the administration of large amounts of alkalis in the treatment of ulcer tends to cause urinary stones. Of 680 patients suffering from ulcer who had received intensive treatment for an average of four months, it was found that 21 (3.1 per cent) gave a history of urinary calculus before they started to receive treatment for ulcer. By contrast, stone developed sometime after the treatment was instituted in only 33 patients (4.9 per cent). In many instances stone did not form until ten to twenty years after the treatment had been discontinued.

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51. Secrétan, M.: Essais d'ozonothérapie endo-vésicale dans les colibacilloses urinaires, Schweiz. med. Wchnschr. **69**:193-196 (March 4) 1939.

52. Kretschmer, H. L., and Brown, R. C.: Do Alkalis Used in the Treatment of Peptic Ulcer Cause Kidney Stones? J. A. M. A. **113**:1471-1475 (Oct. 14) 1939.

This variation, of 1.8 per cent, is "not a grave indictment of the use of alkalis," especially since the figure may be modified by the fact that some of the patients may have had silent renal calculi at the time treatment was begun, and by the consideration that in a cross section of 680 persons approaching middle or later life a normal incidence of renal calculus is certain to exist.

Likewise, it was found that only 1.2 per cent of 1,260 patients suffering from urinary calculi had had previous treatment for ulcer with alkalis. These figures do not support the theory that alkalis used in the treatment of peptic ulcer tend to cause renal and ureteral stones.

UROLOGIC HYPERTENSION

Maher and Wosika [53] reported cardiovascular and urologic studies on 101 patients who presented both hypertension and urologic defects, together with a discussion of their potential relation. The 101 patients comprising this study were all of the Caucasian race; 59 were males and 42 were females.

Twenty-eight patients of this group were dead at the time of writing; necropsy had been done on 11 of these. Thirty-seven patients were still under observation, and with the remaining 36 contact had been lost.

In the group with diseases of the prostate, secondary diagnoses included cystitis, urethral stricture, prostatic stones, hypernephroma, hydronephrosis, perinephritis, pyelonephritis and other results of infection. Patients of the pyelonephritic group also had many secondary complications, and often it was difficult to identify the major lesion as such, making this a heterogeneous group. Complications therein embraced urethral and ureteral strictures, cystitis, hydronephrosis, cystocele, fibroids, nephroptosis, hypernephroma and atrophy of one kidney.

Maher and Wosika stated that there can be no doubt that complete obstruction of the lower portion of the urinary tract, for example by an enlarged prostate gland, produces a decrease in urinary function and is accompanied by hypertension. In the present series prostatic disease accounted for 53 per cent of the male patients who were affected by hypertension. In cases of complete obstruction there is ample evidence that decompression by catheterization allows an improvement in renal function and a decrease in blood pressure. Most of the patients presented had an obstruction low in the urinary tract. In a consideration of the next largest group, of 27 patients, in this series, suffering from chronic pyelonephritis and complications, obvious obstruction was not

53. Maher, C. C., and Wosika, P. H.: Urologic Hypertension: A Study of One Hundred and One Cases, J. Urol. **41**:893-899 (June) 1939.

always readily demonstrable. The dominant factor concerning these patients was that of recurrent infection of the urinary tract with the minor element of obstruction.

Barney and Suby [54] reported a case involving unilateral renal disease with arterial hypertension afflicting a 10 year old girl. The patient was thought to have had salpingitis several years previously. Cystoscopic examination demonstrated a normal bladder. Catheters passed without difficulty to both kidneys; no urine was obtained from the right kidney, which was found infected and atrophic. The blood pressure varied from 185 systolic and 130 diastolic to 200 systolic and 170 diastolic, expressed in millimeters of mercury. At operation the small kidney was found and removed. During the twenty-one months elapsing between operation and the time of writing, the blood pressure had been only a little more than 100.

CHYLURIA

Ray and Rao [55] studied chyluria involving 254 of 12,386 patients who had filarial infestation. The incidence of chyluria in the presence of filariasis was 2.05 per cent, with a ratio of males to females of 9 to 1. For 42 patients careful investigation and study, including, in some cases, cystoscopic examination and excretory urography, were done.

The pathologic changes are largely the result of obstruction of the lymphatic system from inflammatory reaction caused by the presence of adult parasites, the continuous passage of microfilariae and the circulation of their toxins. The obstruction in the thoracic duct or cisterna chyli may be caused by the adult parasite, but more frequently it is the result of inflammatory change secondary to the presence of the parasites.

After the obstruction occurs, there is an attempt to form an effective collateral circulation which results in enormous dilatation of the regional lymphatic trunks. This may appear many years after the death of the adult parasites. These dilated trunks may rupture into the urinary tract, the alimentary tract or the pleural, peritoneal, pericardial and vaginal sacs. When the rupture is into the urinary tract, the chyluria is of renal origin in about 25 per cent of the cases and of vesical origin in about 70 per cent. In the remaining cases chyluria is of mixed origin.

Cystoscopic examination during the flow of chyle shows the characteristic point of leakage from the lymphatic varicosities immediately

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54. Barney, J. D., and Suby, H. I.: Unilateral Renal Disease with Arterial Hypertension: Report of a Case Apparently Cured Following Nephrectomy, New England J. Med. **220**:744-746 (May 4) 1939.

55. Ray, P. N., and Rao, S. S.: Chyluria of Filarial Origin, Brit. J. Urol. **11**: 48-64 (March) 1939.

behind the interureteric ridge or, if the chyluria is of renal origin, the cloudy efflux or the emergent clot at one ureteric orifice.

With the aid of excretory urography, usually but not in every case, communications between the renal calices and the dilated perirenal lymphatic vessels are clearly displayed by the presence of delicate fibrils radiating from the kidneys. In some cases, instead of showing radiating fibrils, the renal outline merges with that of the dilated saccular lymphatic vessels. In nearly half the cases of renal chyluria some obstruction to, or displacement of, the ureters is demonstrated. It is caused either by adhesions or by the pressure of enlarged lymphatic nodes or sacculated lymph channels. The scope of retrograde pyelography is limited, but use of it is indicated in instances of stenosis and deviation of the ureter.

The mode of onset of the condition is spontaneous, but in nearly half the cases there is a history of injury of some sort. In the female patient, in the majority of instances, the condition appears to date from parturition. It is extremely rare in children. Strangury and renal colic result from the retention of clots. The flow is rarely prolonged beyond two or three weeks and generally subsides in about a week. The period of remission may be as short as three or four weeks but is generally much longer. The patient presents other gross signs of filarial lesions. Inguinal lymphatic varix is commonly present in the male patient.

With regard to treatment, no prophylaxis is of any avail, but the simple treatment of complete rest in bed, elimination of fat in the diet, use of aperients and elevation of the foot of the bed may abort an attack if promptly carried out. For the medical treatment of chyluria, intravenous injections of tryparsamide, 2 to 3 Gm. in 10 cc. of distilled water, are found to be effective. Cystoscopy and fulguration usually are successful when the leakage is slight. If clots are present, irrigation of the bladder with a 1:2,000 solution of silver nitrate prior to these measures will be found useful. In severe instances it may be necessary to institute continuous drainage of the bladder for twenty-four hours by means of an indwelling catheter. Patients who have the intractable form of the disease show some displacement of the ureters, and, unfortunately, the condition is bilateral. In instances of neglect or secondary infection, because of the presence of massive or decomposing clots, suprapubic cystotomy may have to be performed. Unilateral nephrectomy fortunately is seldom required. Successful lymphaticovenous anastomosis would provide a satisfactory short circuit for the obstruction to the cisterna chyli or the thoracic duct, but attempts to perform it have failed.

HERMAPHRODISM

Smith, Mack and Murray [56] reported a case of true hermaphrodism, the twenty-third reported case of proved true hermaphrodism and the seventh of bilateral ovotestis.

At operation it was found that the left gonad consisted of a thin film of testis completely enclosing a core of ovarian tissue.

It would be supposed that if the combined ovotestis were brought from the inguinal canal down into the labioscrotum the testis would find the new situation more suitable than would the ovary and would function more prominently. In this case, however, the opposite occurred. The ovarian portion of the ovotestis began to function actively and actually tended to destroy the testis by its own expansion.

Therapy with testicular and thymus extracts was instituted in the reported case in an attempt to destroy the function of the ovary and stimulate that of the testis. Although certain changes were noted during the first weeks of therapy, the menstrual cycle was not arrested, and surgical extirpation of the ovarian tissue was found to be necessary.

Eight months after all gonadal tissue was thought to have been removed, the patient continued to have strong sexual desires for women and frequent penile erections. Whether this was caused by some remaining testicular tissue or by psychic stimulation alone will not be known until after further observation.

In view of the frequency of occurrence of psychoses and neuroses attributed to sexual repression and maladjustment in structurally normal persons, it seems nothing short of miraculous that this patient, subjected constantly since early childhood to unusually severe psychic and emotional trauma, should be eminently sane and stable. On examining the literature, however, it is seen that such an apparently remarkable observation is the rule rather than the exception in similar cases.

Of the 20 cases reviewed by Young it was noted that "the libido or emotions of the patient corresponded to the manner in which the individual had been reared in all cases but one, in which no note was made." In the case reported by Smith, Mack and Murray, on the other hand, the emotions, or libido, were those of a male, although the patient had been reared and had lived the major portion of life as a female.

UROGRAPHY

Wilhelm [57] discussed the technic of vasoseminal vesiculography by way of scrotal vasotomy. This method, in contrast to catheterization

56. Smith, P. G.; Mack, J. R., and Murray, M.: A Case of True Hermaphrodism, J. Urol. **41**:780-800 (May) 1939.

57. Wilhelm, S. F.: Vaso-Seminal Vesiculography: Clinical and Experimental Application, J. Urol. **41**:751-757 (May) 1939.

of the ejaculatory duct, is easily performed. Satisfactory seminal vesiculograms were made in 121 cases without untoward effects.

The emptying of the seminiferous tract following transurethral prostatic resection has been studied in 25 cases. In 3 of these, serial seminal vesiculograms revealed complete retention caused by obstruction of the ejaculatory duct.

In cases of obstructive sterility, vasoseminal vesiculographic examination affords graphic evidence as to the patency of the seminiferous pathways and also may reveal unsuspected lesions in the seminal vesicles. Its routine use before any anastomotic operation is decided on is recommended.

The emptying of the seminiferous tract has been studied by means of serial vasoseminal vesiculograms. It has been found that the seminal vesicles and vasa deferentia normally empty themselves by a slow, more or less constant flow, in addition to, and independent of, ejaculation.

News and Comment

Symposiums to Appear in Later Issues.—During the year symposiums will be published on the following subjects:

"Preoperative and Postoperative Care of Patients," composed of articles by Dr. Cobb Pilcher, on neurosurgery; Dr. Waltman Walters, on the stomach; Dr. John Alexander, on the chest; Dr. I. S. Ravdin, on the biliary tract; Dr. John R. Paine, on the small and large intestinal tracts; Dr. Barrett Brown, on plastic surgery; Dr. Leland S. McKittrick, on diabetes; Dr. Charles B. Huggins, on the genitourinary tract, and Dr. Claude S. Beck, on the heart and pericardium.

"Treatment of Compound Fractures," which will include papers by Drs. H. Winnett Orr, Otto J. Hermann, William O'Neill Sherman and William Darrach.

"Diseases of the Esophagus Requiring Operation."

It is also proposed to publish in June or July a special issue in honor of Dr. Dean Lewis' sixty-fifth birthday.

Southeastern Surgical Congress.—The eleventh annual meeting of the Southeastern Surgical Congress will be held at the Tutwiler Hotel, Birmingham, Ala., March 11 to 13, 1940.

Dr. R. L. Sanders, Memphis, Tenn., is president of the congress, and Dr. B. T. Beasley, 701 Hurt Building, Atlanta, Ga., is secretary-treasurer.

American Association for Study of Goiter.—The next annual meeting of the American Association for the Study of Goiter will be held in Rochester, Minn., April 15 to 17, 1940. The program will consist of papers dealing with goiter and other diseases of the thyroid gland; "dry" clinics conducted by guests of the Association, and operative clinics conducted by the staff of the Mayo Clinic.

The Van Meter prize award of $300 and two honorable mentions will be given for the best essays submitted concerning original work on problems related to the thyroid gland.

Further information regarding the meeting and the awards may be procured from the corresponding secretary, Dr. W. Blair Mosser, 133 Biddle Street, Kane, Pa.